NEW WAYS OF TREATING URAEMIA

THE ARTIFICIAL KIDNEY, PERITONEAL LAVAGE
INTESTINAL LAVAGE

BY

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CONTEous help from Prof R.

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PART I ARTIFICIA special reference to

CHAPTER I ers of the staff of

Nurse M TER

BRIEF SURVEY OF ATTEMPS AT BLOOL W ESKES
CATION IN RENAL URAEMIA

CHAPTER II

THE ARTIFICIAL KIDNEY AS IT IS USED NOW IN THE CLINIC

CHAPTER III

In this work I had the most generous help from Prof R BRINKMAN, Groningen and from a great number of inhabitants of the town of Kampen, but I wish to make special reference to Mr H TH J BERK and to the following members of the staff of the municipal Hospital Engelenbergstichting, Nurse M TER WELLE †, Miss A J W VAN DER LEY en Miss W ESKES

PART I.

ARTIFICIAL KIDNEY.

CHAPTER I

BRIEF SURVEY OF ATTEMPS AT BLOOD- (AND TISSUE-) PURIFICATION IN RENAL URAEMIA.

The clinical notion of uraemia embraces much, and is not at all sharply defined By uraemia an intoxication is understood, caused by an unphysiological rise of the concentrations in the body fluids of a number of products of metabolism, mostly of protein origin by retention or (and) increased formation

According to the origin three forms of uraemia are distinguished

1 Uraemia through renal insufficiency,
2 Uraemia through extrarenal causes,
3 Uraemie d'origine mixte, where both extrarenal and renal factors play a part

The uraemia of extrarenal origin is not discussed in this treatise It may improve with the correction of the extrarenal factors, and should not be treated with the artificial kidney With uraemie d'origine mixte first of all the extrarenal factors must be treated Any uraemia of purely renal origin will eventually be aggravated by the addition of extrarenal factors, which should again be dealt with The way in which this takes place, is incidentally mentioned in the description of the patients in our Dutch book, but it does not form the object of the discussion in this treatise

There remain a considerable number of patients in whom kidney function does not improve with treatment It is with this group, where protein katabolic products must be removed by some channel other than the kidney, that we are concerned

a Excretion through the gastro-intestinal canal

The old way of trying to remove retention products through the intestinal wall has not yet been done away with, it can, however, contribute but little to excretion, just like vomiting and loss of saliva Diarrhoea may have its meaning, it is, if possible, not suppressed in uraemia Intestinal washings are no longer ap-

plied by clinical men with much experience, though a physiological basis is present for this therapy (PENDLETON)

The use of an isolated intestinal loop, through which the fluid runs, as a vividialysator will be discussed in the last chapter of this book

b Excretion through the skin

By the usual sweating-cures not more than 2½ grs of urea N can be excreted per 24 hours, clinicians with great experience such as Fishberg have ceased applying them for years

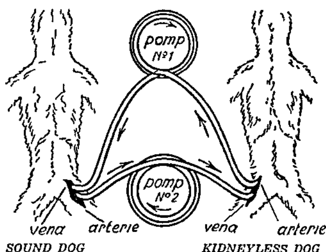


Fig 2
The artery of one dog is connected with a vein of the other dog and conversely

The protracted immersion of the patient in a hot bath may probably attain something more, an experiment done by WITTERMANS gave a cutaneous urea loss of about ½ g per hour, with a blood urea of 40 mgrs per 100 cc It seems probable that in this way something more might be obtained. L MEYLER tried it in a uraemic patient but had to abandon this form of therapy because the patient got too exhausted I have had a similar experience

c Excretion through serous membranes

Peritoneal lavage is discussed on p 91

d Kidneytransplantation and crossed bloodtransfusion

The methods of crossed circulation between experimental an

mals with and without kidneys and the efforts at kidneytransplantations, have had only experimental value hitherto

Transplanted organs atrophy in a short time (ENDERLEN and BORST)

In case of crossed bloodtransfusion (W NYIRI, W THALHIMER) or so-called exchange transfusion one proceeds as has been shown on fig 2 An artery of one dog is connected with the vein of the

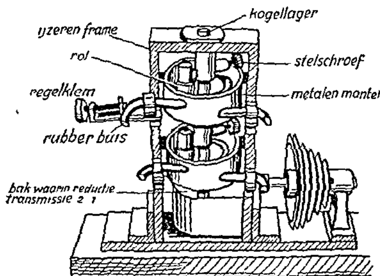


Fig 3
Through this little pump as much blood goes from left to right per timeunit as conversely Lancet 1938

other dog and conversely Through a special pump as much blood goes from the kidneyless dog to the healthy dog per time unit as conversely (fig 3) (W THALHIMER, SOLANDT and BEST) The result is that the total quantity of urea is soon equally divided over both dogs One sees this depicted in the curve in fig 4 I would not connect a healthy donor with a patient suffering from acute glomerulonephritis One does not know beforehand, how the kidneys of the healthy donor would react to this In some other conditions, especially when the patient is a child, one might try the crossed transfusion in man The simplest technics are then those of the ordinary direct transfusion, in which the pump turns alternately to the right and to the left

e Bloodcleansing by venesection or plasmaphaeresis

The withdrawal of half to three quarters of a liter of blood which may be so beneficial in conditions like eclampsia and acute left ventricular failure has no direct significance for the removal of uraemic poisons, the rest N is usually up after loss of blood. Intensive plasma phaeresis i e the with drawal of blood and the replacement of the red cells in saline gives better results

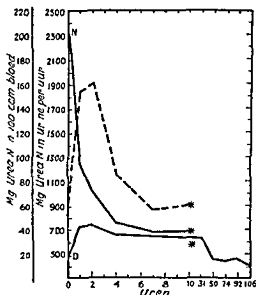


Fig 4

equally divided over both animals

f Vividialysis

In the end we come therefore to the method called by ABEL et al ,vivi diffusion" It was origin ally intended to demon strate the circulation of glucose and amino acids in vivo, but is in addition probably the most effect ive means of removing non colloidal particles from the circulating plasma by diffusion, ABEL ROWN-TREE and TURNER used in this connection the expres sion ,artificial kidney"

An ideal vividialysis must fulfil the following demands

1 the blood must be kept in a closed system outside the body,

2 it must be possible to sterilise this system,

3 the dialysing area must be as large as and the volume of the system as small as possible,

4 the blood must be kept liquid in a harmless way

For keeping the blood liquid ABEL et al used hirudine for which purpose they extracted thousands of leech heads In the case of animals this hirudine did not seem to have any injurious results but experience teaches us, that it cannot be used for human beings The weak point remained the dialysing capacity of their apparatus They employed celloidine tubes with a bore of 6—8 mm and a length of 20—50 cms connected partly in series and partly parallel

The blood was pressed through these tubes by the arterial tension, and flowed back into a vein

In fig 5 is seen, how the blood flows through the celloidine tubes, while the rinsing fluid flows round it in a glass mantle

As rinsing-fluid they used a NaCl solution of 0,55 or 0 6%, as oedemas of the experimental animal appeared when using *0 9 % NaCl*

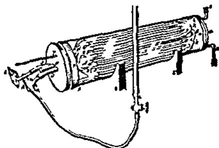


Fig 5
Dialysator according to ABEL, ROWNTREE and TURNER Canule A is attached in an artery of an animal Hirudine flows in

An apparatus with 32 tubes had an area of *3200* sq cms, and a volume of *500—800 cc An apparatus* only carried out on paper *as far as I know, with 192* tubes would have an area of 8179 *sq* cm, but a volume of 2½—3 Ls As ABEL et al could not dialyse more than ⅓ of the total amount of the animal s blood at a time without causing a fall of the bloodpressure, which was already critical this apparatus was only serviceable for a calf or another animal of the same size

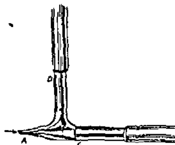


Fig 5a
The arterial canule used by ABEL ROWNTREE and TURNER
A comes into the artery Through C the hirudine is added C tapers to a point which ends close be*hind the point of A The blood is* led through D to the dialysator J Pharm and Exp ther 1913 '14

The cleaning of the apparatus is a problem in itself After cleaning the apparatus was filled with saturated thymol solution, by which it was kept sterile for the next use

An example of application is the following

A dog of 22 Kgs got an injection of I gr of salicylas natricus With an apparatus of 32 tubes in 7 hours *19,1 %* of the injected salicylas natricus could be recovered. *With another dog 24 3 %* A control dog excreted in about *the same time 17 5 % with the* urine It was remarkable that during the dialysis the urineproduction of the kidneys *almost stopped (reduced bloodpressure?) After*

to 40 cms The tubes were tied up at one end, and at the other end provided with a doubly-pierced plug, through which a long and a short glass tube projected The long tube was connected with the artery, the short one with a vein The whole was immersed into a tank with a physiologic saline solution In 3—5 hours 200—700 mgrs of urea nitrogen could be removed by dialysis. THALHIMER hoped to make further experiments in cooperation with Best, but hitherto nothing is known to me of these

Reviewing the literature we see that the clinical application of the artificial kidney has run aground on the following difficulties

1 The want of a harmless and sufficiently reliable agent for the prevention of clotting,

2 the unreliability of the earlier dialysing membranes for which collodion, celloidine or peritoneum were used,

3 the insufficient capacity of the dialysers

As we have at present at our disposal a serviceable means of preventing clotting, i e heparin, and excellent dialysing membranes i e cellophane, the only thing remaining is the *building* of a dialyser with sufficient capacity

*

CHAPTER II

THE ARTIFICIAL KIDNEY AS IT IS USED NOW IN THE CLINIC.

We pass by the various apparatuses built in the last few years to describe only the artificial kidney that was used therapeutically

In cooperation with Mr H TH J BERK the apparatus depicted in fig 12, 13, and 14 has been built in the Kampen Enamelworks

It was our first artificial kidney, suitable for clinical use

It had been made for the greater part of aluminium. Become wiser by experience we built a second and a third kidney, after that finally a series of 4 at a time (see frontispiece) partly of wood, they are based on the same principle

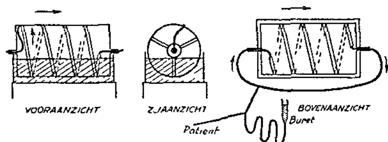


Fig 10
A cellophanetube is wound like a spiral round a big cylinder The blood in the cellophanetube always sinks to the lowest point If the drum turns round, the blood moves from left to right

Principle.

A big cylinder turns with its undermost segment through a tank with rinsing-liquid Round this cylinder a long cellophane-tube has been spirally wound The tube contains only a small quantity of blood This blood sinks by gravity always to the lowest point of the spiral line When the cylinder rotates in the direction of the arrow in fig 10, the blood runs through the spiral line from left to right, always sinking to the lowest point It enters and

leaves the cylinder through the hollow axles, in each of whic is fixed a rotating coupling

By connecting the take up and exhaust tubes with each othe a closed circuit is formed in which the blood circulates rapidl; air bubbles are dragged along

Methods of dialysis.

1 *Fractionated dialysis* This has only historical significanc we used this method to see how our first patient would react t the dialysing of a small quantity of blood

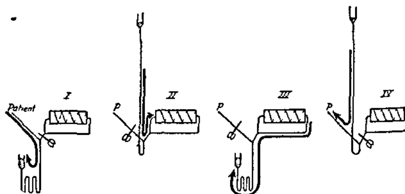


Fig 11
Scheme of fractionated dialysis
I Connection with dialyser shut [illegible]
the patient into the burette — II [illegible]
uremic blood flows out of the bu[illegible]
patient shut off, burette low cl[illegible]
burette. — IV Connection with [illegible]
flows out of the burette into the patient.

A side tube is attached to the circuit branching into two on branch to the patient and the other one to a burette By raising o lowering the burette, blood may be let into or out of the patient and into or out of the dialyser (see fig 11) Using this method only one single venipuncture is necessary In the tube passing to the patient there is a cellophane window, through which ma be seen directly, whether there exists a positive or a negative pressure, and by which one may check if blood is flowing (see fig 20)

2 *Continuous dialysis* A much greater effect is obtained, if the blood is drawn from one bloodvessel, and, after having traversed the kidney only once, led back into another one We did this first

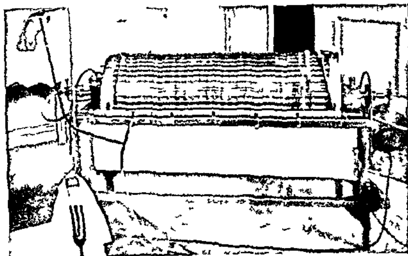


Fig 12
Front view of the f rst artificial kidney
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pat ent s vein

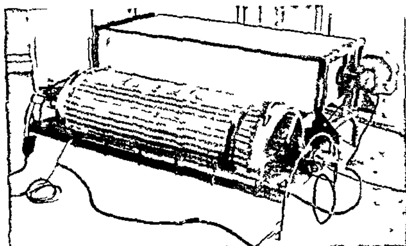


Fig 13

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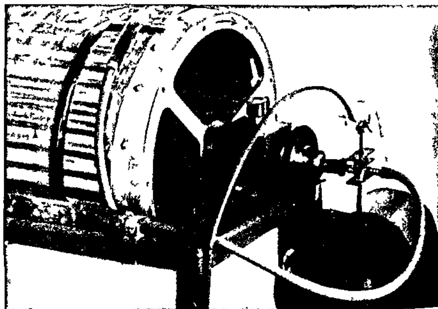


Fig 14
The first artificial kidney half lateral view The cellophane tube is seen to pass into the rubber tube afterwards going to the centre of the cylinder and coming out through the hollow axle

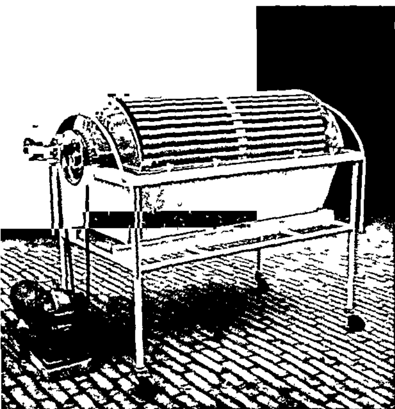


Fig 15
The latest model of an artificial kidney The cylinder is made of varnished lathwork and rotates with its lower segment through a tank with rinsing liquid The splashboards are seen on either side of the cylinder

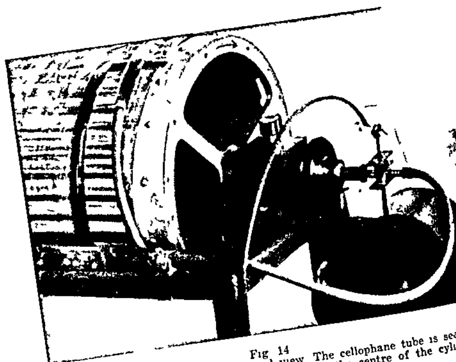


Fig 14

The first artificial kidney half lateral view The cellophane tube is see pass into the rubber tube afterwards going to the centre of the cyli and coming out through the hollow axle

by taking up into the circuit at each end of the kidney a sidetube with a burette, which could be raised and lowered At present we let the blood flow of its own accord from the arteria radialis, and the blood is led back into a vein by means of a rubber tube pump

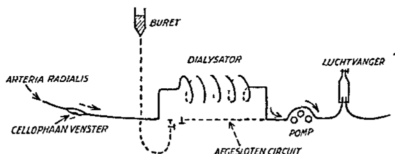


Fig 18

The blood from
e side into the
ped back by a

In the artery and in the vein a glass canula is tied

In order to prevent airembolism, a bubblecatcher has been taken up into the circuit to the patient, in which also clots are sifted

A burette serves for measuring the velocity of the current and can be used to give intravenous infusions to the patient

Details of construction.

(Plans with all measurements are found in the appendix)

The cylinder The cylinder is made of varnished lathing The laths have been screwed on two wooden wheels and project 5 cms over the wheel at the end of the cylinder The cylinder turns with its lower segment through a tank with rinsing-liquid and has two short hollow axles, through which the blood is brought in and led out (fig 15)

The iron frame The hollow axles of the cylinder turn in two plain open bearings (plan III), which are fitted on a rectangular angle-iron frame This frame is provided with legs and can be lifted with the cylinder from the underframe (fig 16)

Resting on ratchets, the frame can rotate round a long side, so that the whole upper part of the kidney may be turned up with the cylinder (see fig 19)

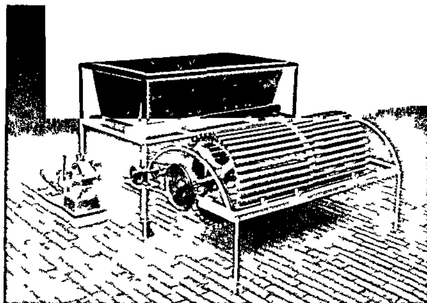


Fig 16
The angle iron frame is provided with legs and can be l fted w th the cylinder from the frame

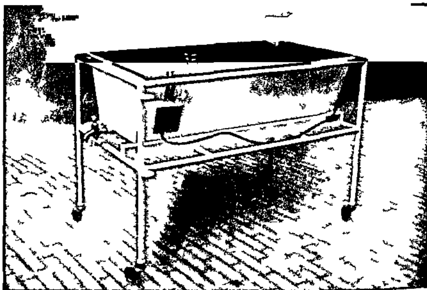


Fig 17
The frame with the enamel bath and the outlet The heating element has been brought in the switch has been put on the bath at the back

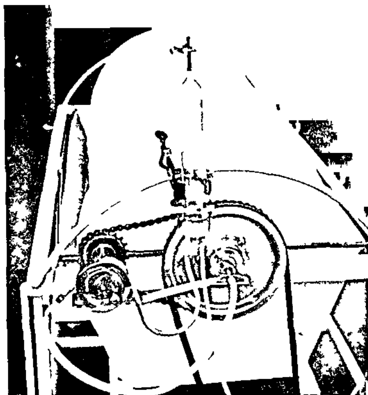


Fig 21
Frontview of the artificial kidney with tubepump and airbubblecatcher The course of the tubes can be seen From the air catcher the blood goes to the patient's vein through the tube which goes almost straight down on this photo

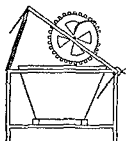


Fig 19
It may be fixed in the tilted position with a little plank, which is very convenient when refreshing the rinsing liquid and checking the cellophane-tube in case of leaks

The bottom of the cylinder can be well seen then, and the bath can be easily refreshed or cleaned

The under-frame is a tube-iron construction on wheels, it bears the enamel rinsing tank In the rinsing-tank is a heating element Formerly we used the bottom of electrical kettles, for this purpose now a more elegant apparatus

Rather than a very vulnerable automatic *heatregulation with a contactthermometer* we use baththermometers, and a simple heating-element, provided with a switch with two positions, resp 1000 and 2000 Watt (see fig 17 and 22)

The Bloodflow through the kidney

The canula and the cellophane-window A glass canula is introduced into the arteria radialis, and the rubber tube, connected with this, is provided with a cellophane window, by means of which one immediately sees if the tube is under positive or negative pressure, and by means of which one can estimate the flow by pinching the tube below the window, the arterial pressure then pumps up the window immediately Canula and pressure-window are found depicted in fig 20

THE PRESSURE WINDOW OF THE OUTFLOW TUBE FROM THE PATIENT

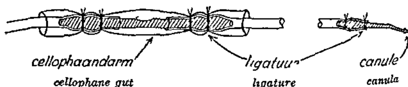


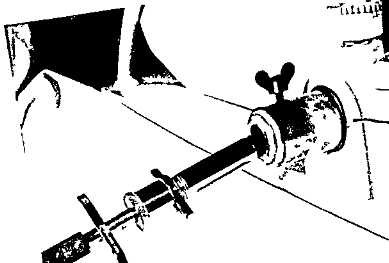
Fig 20
One can immediately see by means of the pressure-window whether the tube is under positive or negative pressure, and if the pressure, is negative the rapidity of the bloodcurrent may be estimated by squeezing the tube for a moment the window is then directly filled with blood

It did not prove to be an advantage to put in a pump in this part of the circuit, when using an artery it is not necessary, when using a vein one runs the risk that the wall of the vein is sucked into the canula

Fig 24

The supply end of the dialyser half lateral

The blood coming on through the rubber tube to the left flows into th rotation coupling mounted in the hollow axle and from there into a secon rubbertube which passes into the cellophanetube on the outside of the drum (This is not a photo of the latest type of kidney but of the second kidne which was constructed)



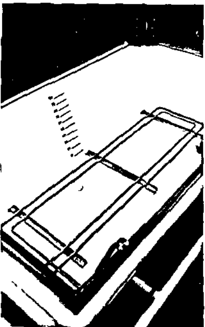


Fig 22
The scaledivision in the bath and the heating element seen from above.

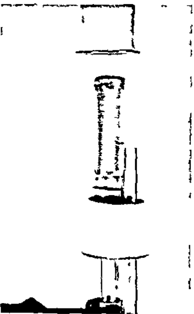


Fig 23
Such a sieve cannot be used for the artificial kidney, on the inner side, down current a thick velvety clot-stratum is formed

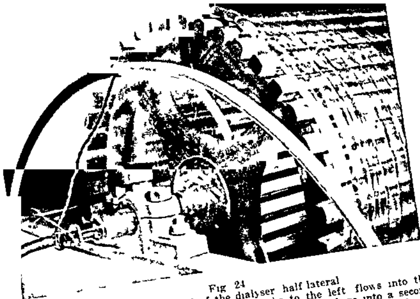


Fig 24
The supply end of the dialyser half lateral
The blood coming on through the rubber tube to the left flows into the rotation coupling mounted in the hollow axle and from there into a second rubbertube which passes into the cellophanetube on the outside of the drum (This is not a photo of the latest type of kidney, but of the second kidney which was constructed)

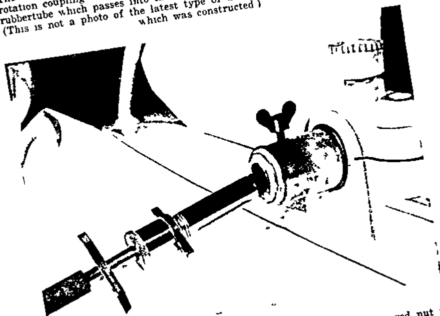
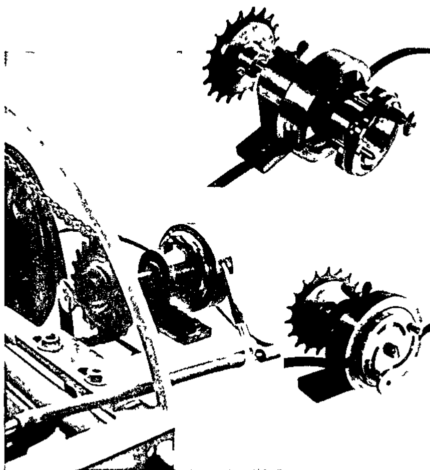


Fig 25
A rotationcoupling, half drawn out of the hollow axle The winged nut is seen with which the coupling is fixed in the axle A counternut has been screwed against the screwcap



An accurate plan of the tubes is found later on in the mounting-scheme A (p 78)

The blood reaches the hollow axle of the cylinder, and the rubber tube passes here into the rotation-coupling (see fig 24)

The rotation-coupling was one of the most difficult parts of the artificial kidney It is depicted in fig 25, fig 27 (and plan II) The inner tube stands still the outer tube rotates with the hollow axle of the cylinder Shutting off is brought about by a cotton packing, soaked in vaseline pressed on to the inner tube by means of a screw socket

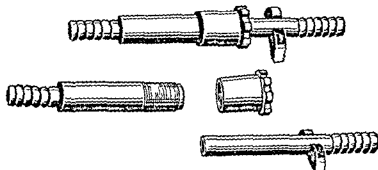


Fig 27
Rotationcouplings. The shutting off is brought about by clinching a cotton packing round the inner tube by means of a screw-cap Nowadays a counter nut is moreover put against the screwcap

The outer tube is fixed inside the hollow axle by means of a winged screw If this fixation does not take place exactly in the centre, the free end of the nonrotating tube whips, so it must be fixed loosely In fig 24 this supple fixation is brought about by a spiral iron wire, on fig 21 in the latest kidneys by a resilient metal plate with a groove in it

The blood flows on leaves the rotation-coupling, and enters the cylinder through a rubber tube This rubber tube is seen on fig 25 It gets out through the spokes of the wheel passes between 2 laths reaches the outside of the cylinder in this way Here it passes into the cellophane tube This is wound in a spiral round the cylinder The blood sinks to the lowest point in the slack moist cellophane tube and when the cylinder turns it runs through the spiral, till at the end of the cylinder it cannot go anywhere else but again into a rubber tube A narrow cellophanetube gives a regular flow, it is advisable to have especially the last piece of the cellophane tube narrow If the cellophanetube springs a leak, it is cut and if necessary one winding is taken out and the ends are joined

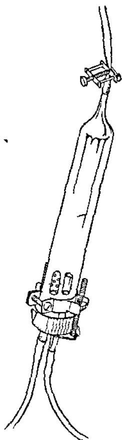


Fig 28
The air and clotcatcher
The blood enters through the right tube, airbubbles gather in the burette on top Clots remain behind before the glass sieve The left tube leads the blood to the patient s vein

together, i e both ends are tied with a double ligature round a piece of rubber tube of about 5 cms length, into which a glass tube has been pushed for rigidity [1])

The blood leaves the cylinder through the other hollow axle, and through the second rotation-coupling It flows some way through the side tube *This side tube* runs over the long side of the iron frame from one hollow axle to the other and is switched off during dialysis it serves for the rinsing of the kidney and for removing the air bubbles (see Sketch E, p 83) Moreover a direct infusion may be made into the patient from the burette through the sidetube to the patient

During the dialysis the blood immediately leaves the first part of the sidetube, and it is pressed back by the tubepump into the patient. So the tubepump does *not* serve for moving the blood in the cellophane tube, that happens through the influence of gravity

The tubepump must work on for hours without disturbances It appeared to us that the modern French (Jouvelet) and Swiss (Transfusor) transfusionpumps were not fit for our purpose, be-

[1]) First one m ... must check (2°) ...

took place From ...

cause the tubes had been mostly mangled to pieces within half an hour The original apparatus of BECK has larger cylinders, and a wider tubecase, and can be used with some alterations Fig 26 (plan IV) shows the tube pump It is mounted on a footplate (plan II), on which it may be shifted after the loosening of a few winged nuts The pump is driven by means of a bicyle-chain On fig 27, one sees at the back of the chainwheel the button with which the freewheel is switched on and off

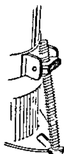


Fig 29
The rubber stopper is kept in its place by means of two screws, otherwise the chance exists, that it will fly off, if the pressure in the burette becomes high

Before the blood goes back to the patient's vein, it passes an airbubble- and clotcatcher, depicted on fig 28 and 29

The blood flows in through the right tube, and leaves the bubblecatcher through the glass sieve next to it Airbubbles which come along with the blood go up in the burette, and remain there If too much air gets into the bubblecatcher, it may be let out at the top of the burette

If the rubber tube is not tied round the burette, it serves as a safety-valve It is always better that this tube flies off than that the burette bursts

Fig 21 shows the front view of the kidney with pump aircatcher and tubes

Instead of the primitive glass sieve in the aircatcher, as is to be seen on fig 28 we also used much finer rustproof metal sieves, e g the sieve of a Baxter-transfusionapparatus, depicted on fig 23

On the inner side of this sieve, down current, a thick velvety clotstratum is formed, probably because heparin is neutralised locally So these metal sieves cannot be used for the kidney

The blood is finally led back into a superficial vein for which again a glass canula is used

The motor The power necessary to rotate the cylinder when the cellophane tube and the bath are filled, is greater than one

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is 23
the
Ar
NEM
II
Corp
Ge

would think A motor of ¼ H P will do As the number of revolutions of our motors amounts to from 1500 to 3000, this must be converted to 35—50 revolutions per minute with a reductio transmission (as is to be seen on fig 15 and 16)

One should not forget to provide the apparatus, especially th bath with an efficient ground-wire

Cleaning and sterilising.

. .. . into contact with bloo
1 (and bubblecatcher a
cle.. .. . rogenic substances, ar sterilised with the same care as with which an apparatus for bloodtransfusion is treated Whether rigors occur or not is for th greater part dependent on this

The tubes and the glass may be sterilised an autoclave or boiled before dialysis, for whi we had a big pan made, the dimensions a found on p 81 New cellophane is pyrogenfre and need only be rinsed and boiled, for whi purpose it is wound on a wooden reel (fig 30 We take a new cellophanetube for each dialys The other parts of the kidney which do n come into direct contact with blood, must l clean, but need not be sterile Cellophane is ir permeable for bacteria and viruses So the steri cellophane tube can be seized with the han The water of the bath is not sterile either, ar need not be so, if it is made up freshly [1])

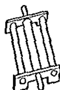


Fig 30 Wooden reel, on which the cellophane tube is wound before being boiled

Expulsion of air from cellophane tube and tubesystem is simpl if the kidney is filled with 1½ L of saline, made to turn, and th saline is streamed through regularly, all airbubbles are take along by the current See further mountingscheme

Keeping of the mounted kidney.

If possible the dialysis should directly follow mounting If th is impossible, the mounted kidney may be kept ready for u (without bathwater [1]), when it is filled with a desinfecting solutio

At first we used a superolsolution ($^1/_{1000}$, oxychinol sulphate) The greatest dis vantage is th e gets dr deprived as it is of the layer of g e manufa turer gave it, and ittle It s mes ta

1) In the beginning som of the bl the artificial kidney, they unless b in the blood of the patient

round the cylinder, and cracks Afterwards we rinsed the kidney with absolute alcohol, and smeared the cellophane tube with glycerine Indeed the tube dried up less, but one should be very sparing with glycerine, and this must be very carefully washed away with big quantities of water later on, as otherwise haemolysis of the blood occurs VAN NOORDWIJK has been able to demonstrate the strong haemolysing action of vestiges of glycerine in vitro and in experiments with the kidney

Rinsing fluid.

(Bathwater as it is used now)

In the beginning we used 70, afterwards 100 Ls of rinsing fluid, kept at a temperature of 37—39° C by a heating element. For the rinsing-fluid clean tapwater is used, clean though not sterile, as cellophane is impermeable to bacteria and viruses The composition has changed in course of time Now we use the following composition

NaCl	0,6 %
KCl	0 04 %
$NaHCO_3$	0,2 %
Glucose	1,5—2 %

To avoid haemolysis the addition of glucose was necessary If the patient has marked oedemata we add more glucose (up to 3 %) to draw the oedema fluid into the bathwater

A weighed-out quantity of salts is put on the bottom of the bath and after that the bath is filled with tepid water as far as the filling-mark for 100 Ls One should take care that the blood-filled cellophane tube does not get into contact with ordinary water, as haemolysis appears very soon in that case It is useless to add $CaCl_2$ to a bath of this composition as the Ca is precipitated by $NaHCO_3$ (One should give Calcium gluconate intravenously)

In the following chapter the composition of the bathwater is discussed

Splashboards.

In order to check the splashing of the bathwater we make use of two splashboards on either side of the kidney They are of aluminium which has been covered with a layer of boatlacquer, and can be easily removed (fig 31)

A cellophanescreen along one long side of the kidney between the two splashboards described above is useful.

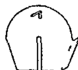


Fig 31



Fig 32

	Artificial kidney	*Human kidney*
Dialysing, resp filtrating area	24000 sq cm	20000 sq cm
Number of glomeruli	one	2500000
Total contents of the cellophanetube resp of the glomeruli	½ L	10 cc
Length of the cellophane tube resp total length of the glomerular loops	30-45 m	75 km
Minutevolume i e quantity of blood flowing through the kidney per minute	100 200 cc	1200 2000
Clearance per minute, i e quantity of blood which is perfectly purified of urea	80 150 cc	54 75 cc
Dialysationmembrane resp glomerulusmembrane permeable for molecules of the following magnitude	no haemoglobin	haemoglobin mol weight 67(
Quantity of ultra filtrate per 24 hours	?	170 L
Circulationtime of the blood through the cellophanetube resp through the loops of one glomerulus	1,5-4 minutes	Part of circulationtim which is 12 18

CHAPTER III

TECHNICAL EXPERIENCES WITH THE ARTIFICIAL KIDNEY GAINED IN CLINICAL USE, AND HINTS FOR THE USE OF THE KIDNEY IN FUTURE.

Fractionated dialysis.

In the case of our first patient we applied a fractionated dialysis in the beginning By way of a single venipuncture 50 cc of blood were drawn off dialysed and infused again In all only 1 l of blood flowed through the kidney at the first dialysis! We did not dare to do more At each of the following dialyses of the same patient more blood was dialysed To reduce the blood-urea to a normal level by a fractionated dialysis was a very lengthy procedure, therefore we changed to a continuous dialysis in which the blood is drawn from one blood vessel and returned into another

Continuous dialysis.

Venipunctures

In the beginning we made it our aim to draw the blood from a vein, and did this by preference with an ordinary venipuncture needle In the case of the second patient 15 l of blood flowed through the kidney in this way in 7 hours time, and in the case of the third 28 l in 8 hours

The fifth patient furnishes a good example of a succesful dialysis with only two venipunctures, 36 l of blood flowed through the kidney in 8 hours time The eight patient was also treated with two venipunctures Nevertheless we abandoned this method.

Puncture of the arteria femoralis was abandoned as well, perhaps without due reason

Glass canulas

There are facts which suggest that heparin is rendered inactive in places where it comes into contact with metal The metal rotating couplings of the artificial kidney got coated inside with a layer of clots (therefore the bore must be a wide one) This was the reason why we ceased using needles, and at present we use exclusively glass canulas of the type shown in figure 20 They

taper conically the narrow point being as short as possible Pyrex glass is said to give less rise to clotting than ordinary glass.

Before dissection of the vein and the artery, we connected a ten cm rubber tube closed with a glass stopper to the glass canulae (fig 32a) This rubbertube was filled with heparine (20 mgr) and saline We found such small tubes easy to manipulate and when both the artery and the vein are prepared and the canulae are tied in the vessels, the glass stopper is removed and the tubes of the artificial kidney are connected

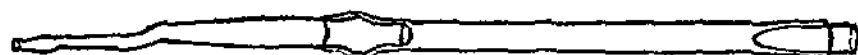


Fig 32a
This rubber tube is filled with heparin and saline

The dissection of a vein

Before the dialysis starts the vein is dissected. We prefer not to take a cubital vein as we like to reserve these for venipunctures on the following days We take either a large vein on the back of the foot or the vena saphena, which is to be found just above the malleolus medialis or a vein on the forearm

Local anaesthesia is administered through one injection opening and we make this exactly above the vein The hole serves us as a landmark when we have to find the vein in the edematous swelling caused by the anaesthetic No adrenalin is to be added to the novocain as this increases the chance of haemorrhages after some hours Bear in mind that each incision may start bleeding because of the strong heparinisation of the patient, and therefore make the wound as small as possible

Our first patient and patient no 11 had such profuse haemorrhages from superficial incisions that transfusions were necessary If one does not know very exactly where the vein goes, the incision is to be made at right angles to the vein's course The incision should not be longer than 2 cms If the vein is dissected by a surgeon, he must be asked to make small incisions

The dissection of the arteria radialis

We have experienced very troublesome haemorrhages from the wound necessary for the dissection of the arteria radialis

A surgical assistant without any experience in this respect dissects an artery practically just as he is used to do that with a vein He pushes a closed pincette under the artery and slides it to and fro with some force But an artery gives off a number of small side branches (see figure 33), which a vein does not. These side branches are pulled off by the treatment mentioned

above, and this gives rise to very pertinacious haemorrhages in the case of an heparinised patient Before starting a haemodynamometer sleeve may be laid round the upper arm The incision must not be longer than 1½ to 2 cms As high as the ligamentum carpi volare the arteria radialis gives off quite a large branch, the ramus volaris superficialis Therefore the incision must not be made through this ligament, but rather somewhat higher up Again and again one feels with the fingertip in the wound to find out where exactly the artery is pulsating In this way unnecessary burrowing and therefore unnecessary chances of haemorrhages may be avoided The fascia covering the artery is divided

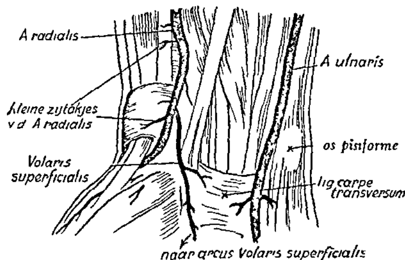


Fig 33
The arteria radialis gives off a number of small side branches (after PALDER KOPSCH)

The arteria radialis lies in a sort of sheath of connective tissue accompanied by veins and sometimes by a smaller artery as well One need not isolate the artery from this sheath, provided these separate vessels are ligated as well The artery must be lifted from its bed as little as possible, and it is never feasible to lay it free over a longer distance than is necessary for pushing the ligatures underneath At least four ligatures are laid, one around the distal end is tied at once, two are knotted round the canula and the fourth remains open for the time being, to close the artery later on when the canula is taken out

When progress is thus far the haemodynamometer-sleeve round the upper arm is inflated to a point far above the systolic blood

pressure, or the proximal thread under the artery is pulled taut

Now the artery is snipped with a pair of scissors and the canula brought into place Take care to get right into the lumen, and see to it that the arterial wall does not split See to it that the canula and the tube are fixed on to the arm immediately, as otherwise they are liable to revolve round their axis and in doing so strangle the artery

Only when the arterial canula lies perfectly is the patient hepa rinised

One minute later the tubes of the artificial kidney can be con nected, and the dialysis started

Both wounds, that of the vein and that of the artery, are closed with clips and provided with a compressive bandage, from which the tubes project

In the case of the patients no 7, 9, 10, and 12 to 25 a vein and the *arteria radialis were dissected according to the rules mentioned* above without any haemorrhage worth mentioning

The removal of the canulas

After the end of the dialysis both tubes are cut off and closed blind, which is *done most conveniently with* a glass stopper

The canula in the vein may be used if necessary for giving bloodtransfusions, infusions of saline etc, if the patient's condition should make this necessary in the first twenty-four hours follow ing the dialyses

This happened e g in the case of patients no 12 and 13 From *the arterial* canula samples of the patient's blood may be taken or blood may be withdrawn should pulmonary oedema become imminent

The blood in these stretches of tube may be prevented from clotting by injecting 50 mg of heparin into the tube from time to time, using a fine needle Only when the patient's clottingtime and bleedingtime have become normal again, so that there is no longer any chance of troublesome haemorrhages, in any case not before the next day, the canulas may be removed from the blood vessels

First the arterial canula is removed, if this is pulled outward somewhat it is generally possible to tie the ligature round the artery proximally of the canula Not a single drop of blood need to be spilt!

Objections to the tying of the arteria radialis

If the arteria radialis is tied the pulse may often still be felt distal to the ligature Functional consequences of the tying of

the arteria radialis never seem to occur For each subsequent dialysis the arteria radialis may be taken a few cms higher up!

About heparin and haemorrhages.

Haemorrhages from dissection wounds may in all probability be prevented by good technique

The bleeding from the nose and the gums during the dialysis of the first patient was not serious We repeatedly saw small haemorrhages in the case of the other patients as well, e g from fissures at the corner of the mouth or small spots of blood in the patient's vomit

The intestinal bleeding in the case of the 15th patient caused by her colitis mercurialis was very serious The patient developed shock, the haemoglobin contents sank to 35 %, so that 1200 ccm of blood were required to raise it again to 63 %

Patient no 9 passed very bloody urine (haemoglobin 30 %), but he had done this previously as well

Patient no 13 developed a haematothorax in addition to a pneu mothorax after an unsuccesful paracentesis caused by the puncture-opening of the needle which had penetrated into the lung and did not close In future we had better abstain from such punctures one day after the dialysis!

One must therefore be warned in case of patients with a colitis mercurialis to keep an ample supply of blood ready, in addition cutting operations are to be avoided shortly after the dialysis but for the rest I believe that we need no longer fear serious bleedings in future, now that we have learned to dissect the blood vessels in the way described above and now that moreover we require less heparin than formerly

Heparin

We must aim at giving as little heparin as possible In the high doses such as we employ (1—3 g each time) heparin not only prolongs the clottingtime, but also the bleedingtime, and it causes a haemorrhagic diathesis which it is hoped will remain latent

At first the quantity of heparin increased with each patient up to 3350 mgr! This was done chiefly because thrombosis occurred in the metal needles

When we changed over to the use of glass canulas we were not afraid to use less heparin, and we could suffice with 1200 mgr per dialysis

A single clot in the airbubble-catcher must not seduce us to give more and more heparine!

Heparin sometimes causes undesirable reactions urticaria, pain

In the second dialysis the KCl was omitted, because with uremic patients the potassium level is increased rather than lowered.

In the third dialysis CO_2 was bubbled through the bath water to lower the pH, this was however not done intensely enough

In the fifth dialysis a bath water was used in which NaH_2PO_4 was present, in the hope of obtaining a more favourable pH, the composition was as follows 0,57 % NaCl, 0,34 % $NaHCO_3$ 0 04 % KCl, 0 01 % NaH_2PO_4

In the sixth dialysis the phosphate was left out again, because the phosphate is generally raised in patients suffering from uraemia

It struck us then that the blood coming out of the kidney after dialysis became haemolytic if kept until the next day We attributed this chiefly to mechanical injury of the erythrocytes, we thought we observed this especially when the cellophane tube was swept clean with the hand at the end of the dialysis, during which the hand repeatedly struck the ridges on the cylinder Whether Superol was run through the kidney or not appeared to make no clear difference

The mechanical injury may be compared with the haemolysis which is seen when blood is ejected from a syringe with too much force against the wall of a glass tube

We then remembered that bloodbanks add glucose to blood for conserving it in order to strengthen the erythrocytes And now, since we add glucose to the bath water, we have not been troubled any more by haemolysis (provided the cellophane tube did not contain glycerine)

In the seventh dialysis the bathwater consisted of tapwater with 0 7 % NaCl and 1,5 % glucose for simplicity's sake There was not a trace of haemolysis This pleased us so well that we maintained the same composition of the bath water for the following dialyses

In the case of patients suffering from oedema (patient no 7 10, 12, etc) we added more glucose namely 2 to 3 % instead of 1,5 % As it takes some time before all the glucose has dialysed in an event which does not take place anyway if the blood flows through the kidney only once, an osmotic water movement towards the bath water takes place Indeed we saw the patient's oedema shrink rapidly so that in some cases wrinkles appeared on the skin

It remains an open question however, whether we must go on with this high concentration of glucose in the bath water Perhaps we shall prefer acacia or Oncocapain a substance therefore which has an osmotic effect but cannot pass through the cellophane itself The quantities required would, however, be very large and perhaps the foaming will become a drawback

The $NaHCO_3$ we left out for the time being after the seventh dialysis as we did not trust it altogether with regard to haemolysis Only in the case of the 5th patient we became so scared of increasing a probably existing acidosis that 0,2 % $NaHCO_3$ was added to the bath water

In the case of patients treated in Kampen we have kept to this later on We did not consider it necessary to add KCl to the bath water as the potassium content of patients suffering from a *serious uraemia is generally raised*

Only much later when in one dialysis 120 litres of blood ran through the kidney it became clear to us that too extensive changes in the mineral spectrum of the blood may occur which in such a large dialysis apparently cannot be compensated by the organism From then we added 0 04 % KCl to the bath water

Regarding the calcium content of the bath water With the 6th patient we were surprised to see that the calcium content of the blood from the kidney (8 mgr per 100 ccm) had sunk so little Only about 40 % 4 mgr per 100 ccm therefore of the calcium present in the blood is present in a rapidly dialysable state The tapwater proved to contain 4 mgr of calcium per 100 ccm therefore an equilibrium existed on both sides of the membrane

If CaCl is added to a bath containing $NaHCO_3$ as well the calcium is precip tated in the form of $CaCO_3$

Consequently in the case of the 15th patient (first dialysis) we saw little result from such an attempt (the addition of 0 027 % $CaCl_2$ to the bath water) The calcium contents of the bath water fell to 1,3 (duplicate 1 9) mgr per 100 ccm and the calcium content of the patient s blood serum fell from 10 to 6 3 mgr per 100 ccm

The solution might be found in having the cylinder rotate in a closed space e g under a cover inside which a mixture of air or gas with 5 % CO_2 is maintained — which might bubble through the bath water as well — a pH desirable in all respects might then be obtained and in this case the CaCl would remain dis solved

We have shrunk from the technical execution and for the time being we give 1 or 2 grams of gluconas calcicus intravenously i.e in the tube during the dialysis

In practice it is easy to choose the composition of the bath water in such a way that it may be used for various patients The mineral spectrum of the patient follows the bath water and if the composition of the bath water is adapted to a normal mineral spectrum as much as possible the patient s plasma will be nor malised in this sense as well

The composition of the bath water which we recommend at present is NaCl 0 6 % $NaHCO_3$ 0,2 % KCl 0 04 % glucose

1,5—2 %, do not forget 2 × 1 gram of gluconas calcicus intra venously

If one compares the concentrations of the various ions in the bath water with those in the blood plasma, the following calculation is obtained for the bath water

Bath water everything expressed in mgr per 100 ccm

600 NaCl	=			364 Cl	+	236 Na
40 KCl	=		21 K +	19 Cl		
200 $NaHCO_3$	=	53 vol % CO			+	55 Na
	=	53 vol % CO_2	+ 21 K +	383 Cl	+	291 Na

The normal values for the bloodplasma are

50—70 vol % CO 16—20 K 340—389 Cl and 310—330 Na

These numbers are expressed per 100 ccm of plasma, to obtain a correct comparison for the dialysis the startingpoint must be the plasma water

Assuming that the bloodplasma contains 8 % albumen, which however, is much too high an estimate for many of our patients the above numbers must be multiplied by $^{100}/_{92}$ = ± 1,1 Thus we obtain

the normal values in the plasmawater expressed in mgr p 100 ccm

55—77 vol % CO_2 18—22 K 370—420 Cl 340—360 Na

We are still on the low side with our bath water, and especially the sodium content is too low for the following reasons

1 The bath water is alkaline, and we dare not let too much $NaHCO_3$ dialyse in at a time

2 The electrolyte level of most patients is generally lowered. By introducing large quantities of NaCl one risks pulmonary oedema We see that our last bath has nearly the same composition as DARROW's „interstitial salt solution", which we used in our very first dialysis ! On revient toujours

Foaming

If foaming of the bath water is excessive during the proceedings, blood (albumen[1]) has entered it, most often there is a leak then. The foaming may be very troublesome, an argument in any case for changing the bath somewhat earlier and looking for the leak[1])

[1]) If there was no leak in the cellophane tube we could not detect any albumen in the bath water with the usual methods

Evaporation

The evaporation of the bath water during the dialysis is marked sometimes 10 % The addition to the bath of some tapwater from time to time is advisable as otherwise the concentration becomes too high The losses by splashing must *not be replaced in* this way

Haemolysis

Haemolysis of the blood in the artificial kidney is accelerated by

1 Incorrect composition of the bath water Hypotonicity incompletely dissolved salts in the beginning

2 Too little glucose

3 Mechanical injury to the erythrocytes (see page 34)

We therefore reduced the speed of the cylinder to 25 revolutions per minute

4 A long stay of the blood in the kidney erythrocytes running through quickly soon recover again when they are back in the patient

5 Use of banked blood more than one day old for transfusion during dialysis

6 Presence of glycerine

J VAN NOORDWIJK could demonstrate with experiments in vitro and in an experiment with cow s blood in the kidney that small quantities of glycerine increase the chance of haemolysis

CHAPTER IV

CLINICAL PICTURES, IN WHICH TREATMENT WITH THE ARTIFICIAL KIDNEY IS TO BE CONSIDERED SURVEY OF THE FIRST 25 PATIENTS TREATED WITH THE ARTIFICIAL KIDNEY.

Uraemic conditions suitable for treatment with the artificial kidney but of which we lack experience up till now — such as anuria following a crush syndrome, anuria following eclampsia gravidarum, anuria in cases of symmetrical necrosis of the renal cortex, — are not discussed neither is the possible treatment of intoxication by hypnotics [1])

I Chronic and subchronic uraemias.

(Patient no 1, fig 40) A woman of 29 years with a malignant hypertension and contracted kidneys was sent in for treatment under the motto that nothing was to be lost and perhaps a temporary improvement to be gained On arrival she had a haemoglobin of 35 %, and severe cardiac failure with orthopnoea Within a few days the following complications developed a pericarditis, parotitis, pleuritis and an otitis media
The hope that the renal function would recover to some extent has not been fulfilled The patient could finally be kept alive for 26 days with her blood urea remaining at a constant level, although she excreted only very little urine

(Patient no 2) Man of 60 years with bilateral renal tuberculosis, cachexia and uraemia
One dialysis was applied in which the dehydration and the shock were combatted as well The next day the man was in a much better condition the diuresis increased The pains in the bladder were of such a nature that we believed we had no right to prolong this man's life any further

(Patient no 18) A married woman of 54 years Four months before admission she had an acute glomerulo nephritis and was afterwards seen as out patient by Dr SCHALM Many red cells were always present in the urine and the blood pressure rose to 240/125 A sudden anuria developed with no abnormal findings on cystoscopy and pyelography The blood pressure fell to 140/70, presumably left ventricular failure had set in

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[1]) Note at the correction Dr E G L Bywaters British Postgraduate Medical School, Hammersmith [illegible] by the [illegible]

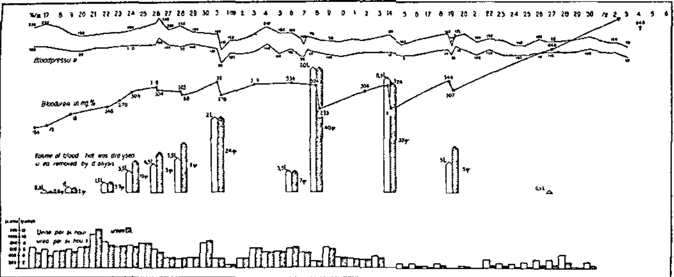


Fig 34

Graph of patient no. 1, a woman of 29 years suffering from a malignant hypertension with contracted kidneys She was the first patient to be treated with the artificial kidney In the top of the figure the systolic and diastolic bloodpressures have been indicated, the difference between them being shaded The percentage of urea of the blood has been indicated by a drawn line It is shown to sink each time after a large dialysis, e g from 339 to 278 mgr per 100 cc The dialyses are reproduced by *columns. The white column indicates the quantity of blood dialysed*, the shaded *one* the *quantity of urea removed by dialysis* Right at the bottom the quantities of urine passed per 24 hours are found represented by white blocks, the quantities of urea excreted with this urine are indicated by shaded blocks

Eight days after the onset of anuria she was dialysed The blood urea fell from 304 to 46 mg %; the chloride content of the blood (expressed as NaCl) rose from 530 to 550 mg %, the alkalireserve rose from 26 to 42 vols % Every effort was made to increase her blood pressure, and the day after dialysis it had risen to 160 90, and she passed 30 cc of urine. The same evening venesection was performed on account of pulmonary oedema, and the following evening she died from heart failure

Post mortem Subchronic glomerulo nephritis

(Patient no 23) An unmarried woman of twenty History of in definite illness for only a few weeks She became progressively uraemic with muscle twitchings and convulsions Her blood pressure was *150/120* She was taken into the hospital at Kampen and immediately connected to the artificial kidney The blood urea fell from 382 to 170 mg % per 100 cc, the dialysis removing 69 gr of urea Plasma chlorides (as NaCl) fell from 685 to 662 mg per 100 cc, and the alkalireserve rose from 19 to 53 vols %

During and after dialysis the patient had convulsions suggestive of tetany The calcium plasma level was 5 5 mg before, and 5,3 mg per 100 cc after dialysis, although 0,5 gr calcium gluconate had been given intravenously Despite a further 2 gr of calcium gluconate the calcium level remained 5,2 mg per 100 cc The general condition of the patient deteriorated rapidly, perhaps aggravated by an unfavourable reaction to morphine, and she died 28 hours after dialysis

Post mortem Contracted kidneys were found, weighing 54 and 48 grams

It is clear that the first two patients could not be saved by the artificial kidney Patient no 18 was treated only because there was no other hope for her The phenomenon of anuria after a sudden fall of blood pressure in a hypertensive may be encountered both in chronic and acute uraemia Patient no 23 was treated as it was not certain that a chronic nephritis formed the background of her uraemia, the intractable hypocalcaemia precipitated death

Generally speaking, the chronic uraemias are no indication for treatment with the artificial kidney. There are chronic uraemias which are aggravated temporarily by an intercurrent infection, a dysenterylike diarrhoea, an operation, and so on If this infection or the operation is over and the patient does not succeed in overcoming the aggravation of his uraemia by himself, one might try to restore by a dialysis the patient to the level on which he formerly kept his equilibrium The uraemia caused by hypertrophy of the prostate, temporarily aggravated by an operation, can be a favourable example and is discussed later

Apart from that, one has to consider in every case of uraemia with contracted kidneys whether the patient suffers chiefly from his uraemia or from the consequences of the hypertension The latter are not done away with by the dialysis' The cerebral pheno mena, the retinitis, the angina like complaints and failure of the left ventricle are all mainly caused by the hypertension

urine when the artificial kidney had to be placed next to their beds through lack of space, but I do not want any one to believe that the diuresis was started by placing the artificial kidney next to the bed In my opinion one had better abandon all methods intended to start the diuresis in patients with glomerulo-nephritis

(Patient no 3) Man of 43 years, acute glomerulo nephritis For 14 days he passed less and less urine, until he produced only 50 cc of urine a day His doctors being at their wits' end, both kidneys wer decapsulated and both kidney stalks denervated After that the patien passed even less urine but clinically he still made a good impressio and he was 1 460 mg per 100 cc fore th dialysis the with th artificial ki e end o the dialysis

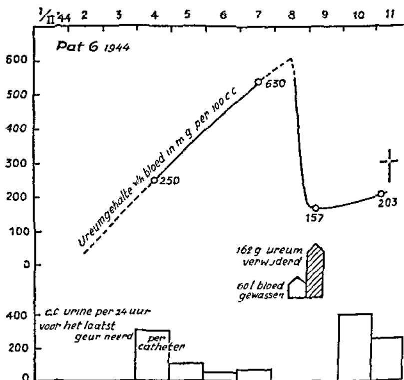


Fig 36
Graph of patient no 6, a woman of 34 years with an acute glomerulonephritis Before the dialysis she produced only very little urine.

(Patient no 6) A woman of 33 years enormously fat, developed an acute glomerulo nephritis at the beginning of scarlet fever During the last five days before the dialysis she passed less and less urine bei

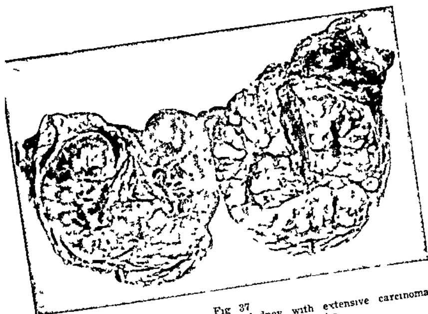


Fig 37

Kidney of patient no 9 The right kidney with extensive carcinoma The left with acute glomerulo nephritis

bloodpressure before the dialysis was 130/80 The blood urea was 630 mgr per 100 cc The patient slept almost continually and when she awoke for a few moments she was desorientated

During the dialysis she awoke and became fully conscious The urea fell to 157 mgr per 100 cc The bloodpressure rose to 170/80 The diuresis started!

Two days later she died unexpectedly of broncho pneumonia with pulmonary oedema

(Patient no 9) A man of 51 years suffering from an acute glomerulo-nephritis which had started with ileus like symptoms, had anuria for 6 days He was treated with the artificial kidney, 96 gr of urea were removed by dialysis and the blood urea fell from [illegible]

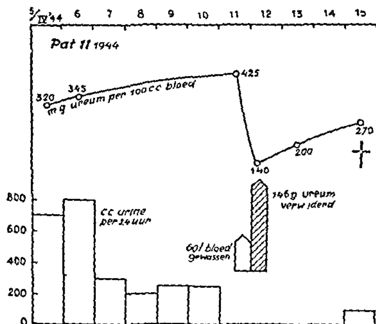


Fig 38
Graph of patient no 11, a man of 19 years, with a glomerulo-nephritis of 20 days duration

(Patient no 11, fig 38) A man of 19 years had a glomerulo-nephritis for 20 days The quantity of urine sank to 250 ccm a day The bloodpressure was 185/110 and the patient was ominously pale The blood urea was 425 mgr per 100 cc before the dialysis 146 grams of urea were removed by the dialysis and the blood urea fell from 425 to 140 mgr per 100 cc

Diuresis did not set in The bloodpressure remained high He died of cardiac failure four days after the dialysis

Patient no 17

A woman of 67 years was admitted 8 9 45 to the surgical ward by my colleague Dr KEHRER in a serious condition She had a high fever a very painful and distended abdomen, an enlarged and palpable gall bladder with much infiltration a slightly yellow skin and almost complete anuria The small amount of urine still produced was cloudy, a dark red brown and contained very much albumen erythrocytes leucocytes and casts The blood pressure was 150/60 Thus she was suffering from 1st *cholecystitis* with *pericholecystitis* and *jaundice*, 2nd an acute *glomerulo nephritis* with almost complete anuria, (a *hepato renal* syndrome if you like)

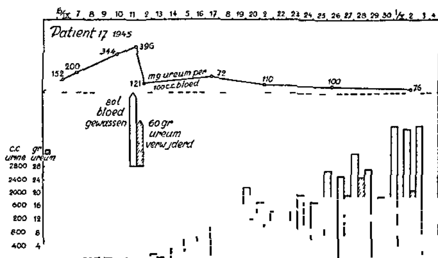


Fig 39
Graph of patient 17 woman 67 years old with glomerulo nephritis
Dramatic improvement by dialyses Recovery

For 2½ days the patient was given sulphathiazole (6 gm per day) after that no more as the sulphathiazole reaction in the blood against the anuria remained constant (on 11 9-45 the free sulphathiazole in the plasma was *still 8 mgr per 100 cc*

The temperature of the patient dropped slowly, but the production of urine did not recommence and after 8 days on 11 9 45, the urea content of the blood rose to 396 mgm per 100 cc The potassium content of the blood had risen alarmingly to 55 mgr per 100 cc and the alkali reserve was 40 vols %

The clinical condition of the patient had become much worse She slept and snored the whole day long after much shouting at her she stammered with difficulty one word with a very dry mouth and im*mediately fell asleep again A few days before when she had been* able to speak more her mind wandered She had oedema of the back and legs Her pulse was still good and her blood pressure 160/110

On 10 9 Dr KEHRER performed a cystoscopy the right *ureter* was

healthy, in the left ureter the *catheter* could not reach further than 2 cm from the bladder

A pyelogram showed a normal pelvis on the right side, the production of urine did not commence after the renal pelvis had been washed

On 11 9 the patient was treated with the artificial kidney

80 liters of blood flowed through the kidney in 11½ hours, 60 grams of urea were removed by the *dialysis* and showed in the bathwater The blood urea dropped from 396 to 121 mgr per 100 cc

During the dialysis her condition was very alarming for some hours but at the end her general condition was good The blood pressure was 160/80, the potassium content (that could be determined in spite of the heparine) had dropped to 19 mgr per 100 cc!

The clinical improvement was clearly to be seen after some hours of the dialysis and a day after that her mind was completely clear again She was not sleepy, talked much and easily and made sensible plans for the future

She had a moist normal looking tongue her temperature was between 36 5—37 3° C and her pulse was between 78—110 Her haemoglobin was 65 % The oedema remained unchanged Although we ligatured the left arteria radialis 2 cm above the ligamentum carpi volare *the pulse could be felt*

The production of urine during the first few days was still not sufficient The urea rose to 172 mgr a day while the concentration of the urine slowly improved After the dialysis the patient vomited

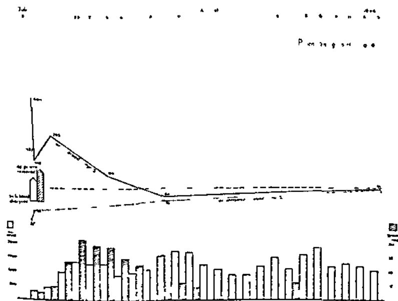


Fig 40

Graph of patient no 24, a girl aged 13 with acute glomerulo-nephritis anuria for a week and pulmonary oedema with bronchopneumonia She recovered

considerably for some days, while her abdomen was still painful and distended, his however, recovered soon

Two months after the dialysis 11-9-45, the patient was very well The urine still contained some albumen and sometimes some erythrocytes The blood-pressure was 175/90 7 months after dialysis I saw her again in excellent condition.

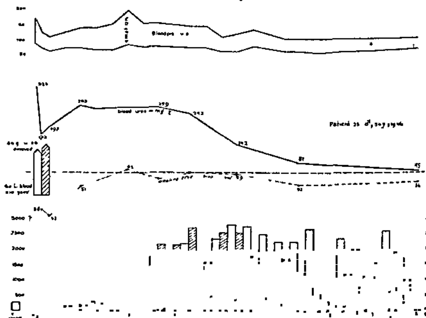


Fig 41
Graph of patient no 25 Man of 54 years old with acute glomerulo-nephritis pulmonary congestion, etc. Recovery

Time will prove whether a chronic *nephritis* will develop from th acute glomerulonephritis which she survived in September. But even if i does, the threatened danger to life, based on the acute uraemia, has bee dispelled with success.

(Patient no 24) Girl of thirteen Got soaked through in a walkin contest, and one week before coming into hospital developed acut glomerulo-nephritis ...

In four and a half hours of dialysis 45 grams urea were removed and the blood urea fell from 364 to 140 mg per 100 cc Not only wer no transfusions given but blood was drawn off to combat the pulmonar oedema Penicillin was administered for the lung infection.

Diuresis started during dialysis gradually increasing afterwards an the patient made an uneventful recovery.

(Patient no 25) Man of 54 with acute glomerulo-nephritis, Nin days before admission complained of general malaise; the next day h

twice fell down due to giddiness and then remained in bed with pain in the abdomen and back and facial oedema developed

On admission (9 8 46) he had passed very little urine during the last five days and complained of lack of sleep headache nausea and hiccoughing On examination he showed uraemic exanthema mild oedema was dyspnoeic and a chest x ray showed left sided cardiac enlargement and pulmonary congestion Bloodpressure 170 90

jectively improved when a further 250 cc of blood was removed This 1000 cc of blood was not returned to the patient at the end of dialysis

The condition of the patient was very good after treatment and diuresis slowly increased Four weeks after dialysis he was very well and was discharged with slight albuminuria and a few red cells in the urine

Reviewing the short case histories of the above mentioned seven patients with an acute glomerulo-nephritis it is clear that patient no 9 in whom an extensive carcinoma existed may be left out of further discussion

Patient no 3 was connected with the artificial kidney too late Here we see for the first time that a patient clinically apparently well suddenly gets worse

Patient no 6 died unexpectedly of bronchopneumonia with pulmonary oedema Apparently she had not sustained the previous intoxication with impunity A great pity for the diuresis setting in made us hope for the best

Patient no 11 died of failure due to hypertension It is probable however that his whole organism and his heart too had already suffered greatly by the previously existing serious uraemia

When patients such as the above are treated with the artificial kidney one must count upon only a few being so fortunate as to be saved.

Forms of glomerulo nephritis with gradually decreasing diuresis show less tendency to recover than cases beginning with acute anuria

Patient no 17 seemed clinically so desperately ill that the author considers she would have died without the aid of the artificial kidney Patient no 24 a thirteen year old girl proves that a manifest pulmonary oedema need not be a contra indication to treating a patient with the artificial kidney if a severe anuria makes it desirable The blood coming from the radial artery was dark and oxygen was given for several days Penicillin was administered for the bronchopneumonia Apart from a slight albuminuria the girl is in perfect condition now three months after treatment

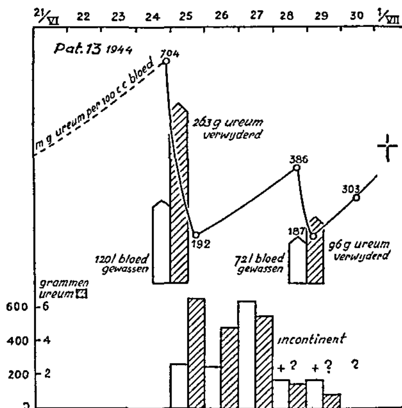


Fig 43
Graph of patient no 13, a man of 38, for 3 weeks suffering from a glomerulo-nephritis. Although he produced about 1 litre of urine a day at home, the blood urea rose to 700 mgr per 100 ccm

(Patient no 16) A man of 67 a history of four weeks malaise, and one week symptoms of acute glomerulonephritis, vomiting, oedema and headache On admission he was drowsy and disorientated Urinary out put was 200 cc per 24 hours Bloodpressure 230/110 Pulse 116 Gallop rythm of the heart

Two days later he was connected to the artificial kidney 123 grams of urea were removed, and the blood urea fell from 472 to 172 mg per 100 cc The day after dialysis the patient's general condition was very good, and his mental state normal Despite all efforts diuresis did not set in, and six days after dialysis his blood urea had again risen to 423 mg per 100 cc Two days later he died, just before he was going to be connected to the kidney for the second time

(Patient no 19) A married woman of 48 An attack of acute glomerulonephritis, and one week later pulmonary congestion, which she survived Her daily urinary output went up to 2 litres and her blood pressure rose to 170/100 In the course of a few days a complete anuria developed and her blood pressure fell to 110/80 It would seem that the

heart could no longer maintain the pressure demanded by the kidneys She was admitted to hospital three weeks after the start of her illness when marked oedema was present Haemoglobin 36 %, blood urea 380 mg per 100 cc, alkali reserve 38 vols % and xanthoproteins 93 %

In the hope of improving the blood pressure and the haemoglobin level carefully controlled blood transfusions were given, but a temporary auricular fibrillation set in Dialysis was started next day, 80 grams of urea were removed, and the blood urea fell to 152 mg per 100 cc, and the xanthoprotein to 60 %, the alkali reserve rose to 47 vols %, and the haemoglobin to 57 %

After the dialysis the patient's condition was good The same day, in company with the nurse who was attending her, she developed rhinitis and a sore throat and the general picture of influenza with a high temperature In the afternoon she started fibrillating again, and died that night in cardiac failure

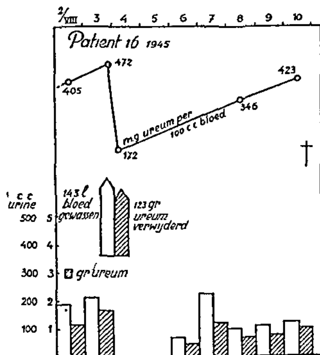


Fig 44
Graph of patient 16, a man of 67 years Glomerulo-nephritis for 5 (?) weeks Diuresis did not improve

Patient no 8 came under treatment so late because it was wrongly thought that a chronic nephritis was present

The production of 1 to 2 litres of almost clear urine a day with a S G of ± 1,011 does not yet prove the existence of a chronic nephritis, neither does it exclude an acute one!

Patient no 13 has reached a blood urea of a height rarely reached by any one This man too we should have preferred to treat earlier

The life of patient 16 was probably lengthened for a week by dialysis Patient 19 died from heart failure as was expected

It seems to us that the prognosis of this group of patients is extremely bad although dialysis may prolong life for a few days

B ACUTE URAEMIA AFTER OPERATIONS

1 *Forms of acute post-operational uraemia progressing with oliguria or anuria*

(Patient no 4) In a man of 68 years both the ureters had been transplanted into the sigmoid because of carcinoma vesicae No urine entered the rectum The man's circulation was bad and the patient was in shock before the dialysis started During the dialysis the diuresis set in but the urine did not reach the sigmoid as was planned it entered the peritoneal cavity from which it emerged through the wound and the dressings

When we observed this the dialysis was stopped

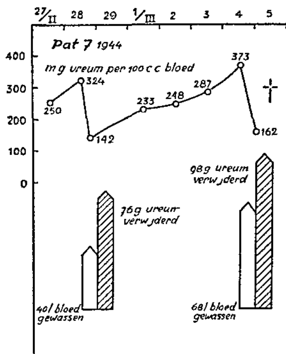


Fig 45
Graph of patient no 7, a man of 30 years whose right kidney containing a carbuncle was removed After the operation anuria

(Patient no 7, fig 15) In a man of 30 years in whose case the diagnosis "carbuncle of the kidney" had been carefully made the right kidney was taken away After the operation a complete anuria arose The patient was twice treated with the artificial kidney and died of the consequences of his staphylococcal sepsis of which the carbuncle of the kidney had only been a part

At necropsy an aplastic left kidney was found in which even microscopically no renal tissue could be discovered (fig 43)

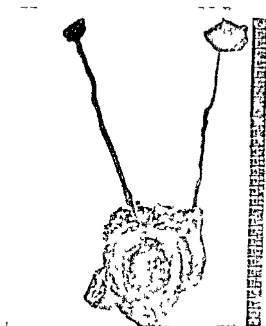


Fig 46
Bladder of patient no 7 Right ureter ligated (in the top of this photograph) after nephrectomy Left ureter gradually narrowing till completely obliterated Right at its top the atrophic left kidney

(Patient no 14) A man of 48 years had acute dilatation of the stomach, and after an exploratory laporatomy in the lower abdomen a resection of the stomach was performed After the operation a pneu- [illegible] th sulphathiazole Eight days after [illegible] was combatted with intravenous [illegible]

[illegible] urea content of the blood rose to 548 mgr per 100 ccm The potassium content of the blood serum rose to 25 mgr per 100 cc, and the alkali reserve was 36 vol % The patient was dying on arrival in Kampen, nevertheless he was treated with the artificial kidney, but he survived the dialysis only by a few hours

No one will blame the dialysis for not having been able to help these three patients. Concerning the cause of patient no 14 's oliguria we are still in the dark

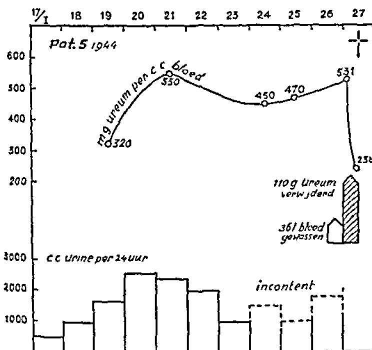


Fig 47
Graph of patient no 5, suffering from a uraemia originating after an operation and an infection The diuresis was ample, but the concentration of the urine was poor

2 *Forms of post operational uraemia where the patient does pass urine, but where the concentration of the urine is so bad that nevertheless uraemia arises or persists*

(Patient no 5 fig 47) A man of 58 years in excellent health came into hospital for an inguinal hernia Following the operation he developed a high temperature an exanthema and a pulmonary infiltration, which was treated with sulphathiazole After 5 days he was drowsy and and uraemic After 14 days the diuresis rose to 2 litres per 24 hours, but the man s general condition deteriorated rapidly
On arrival in Kampen he was in a bad condition Before the dialysis he was precomatose but during the dialysis he awoke and spoke with his family Sudden death through apnoea

In the case of this patient we are all at sea as to the cause of the uraemia just as in the case of patient no 14 The former s uraemia persisted in spite of a diuresis of at least 2 litres per 24 hours
Microscopically no pathologic signs of any importance were to be found in either of these two patients' kidneys i e not a trace of a nephritis
We have not been fortunate with these two patients as they came in for treatment too late yet **I believe that the post operational uraemia and anuria must belong to the most promising indications for treatment with the artificial kidney, complete recovery must be possible In addition one is less encumbered by a hypertension with all its unpleasant consequences, as is the case with a glomerulo nephritis**

C Acute uraemia caused by or accompanied by intoxications

1 *Mercury bichloride intoxication*
Mercury bichloride itself is scarcely removed by the dialysis as the Hg ion forms non dialysable compounds with the plasma albumen

(Patient no 12) A woman of 24 years irrigated herself by mistake with a solution of 1 gram of mercury bichloride in 250 ccm of water The consequences were necrosis of the vaginal walls violent pain and necrotic ulcers in the mouth diarrhoea and vomiting besides almost instantaneous anuria Her general condition deteriorated rapidly although by a dialysis five days after the intoxication the urea content of the blood was reduced from 265 to 89 mgr per 100 cc Two days later she died of broncho pneumonia (with pulmonary oedema) probably due to aspiration of the gangrenous discharge from the terrible ulcerating mouth and throat

(Patient no 15 fig 48) A woman of 47 years took a table spoonful of a draught, by mistake made with chloretum hydrargyricum 10/300 instead of hydras chlorali The main ensuing developments were serious gastro enteritic troubles with diarrhoea and very soon a complete anuria After eight days the urea content had risen to 289 mgr per 100 cc and it fell to 159 mgr per 100 cc after the first dialysis The abdo-

minal symptoms caused the gr[illegible]
the second dialysis. She was al[illegible]
second dialysis started She h[illegible]
which the heparinisation will [illegible]
could be controlled by blood transfusions

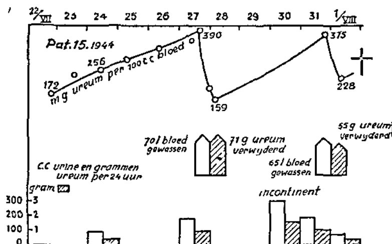


Fig 48
Graph of patient no 15, a woman of 47 years with anuria from mercurial nephrosis

These two patients did not die of the consequences of their anuria The first died of aspiration pneumonia from the gangrenous stomatitis The second died of the intestinal complications, especially of her colitis Taught by experience we hope in future to prevent the former by sucking away the saliva, and the latter by cutting out the colon absolutely in such cases of serious colitis with a double-mouthed ileostomy, to prevent the thin corrosive faeces from running down the ulcerating colon.

Nevertheless the uraemia due to mercurial nephrosis must be a good indication for treatment with the artificial kidney. [1] Especially as the mercurial nephrosis regenerates to a miraculous extent if the patient remains alive, but this takes time In the case of our second patient, the diuresis was already starting again, and in the

postmortem examination of the kidneys regeneration was clearly visible The chances of recovery rise with every day gained for the patient in this period

2 *Uraemia after use of chemotherapeutics*

Several chemotherapeutics, e g sulphathiazole and sulphapyridine may give rise to blocking of the urinary passages by crystals Apart from this mechanical obstruction another form of anuria is supposed to occur not accompanied by the formation of crystals

(Patient no 10 fig 49) A man of 50 years developed an extensive pulmonary embolism three years ago and after that he was under medical treatment for fibrillation with a dilated heart

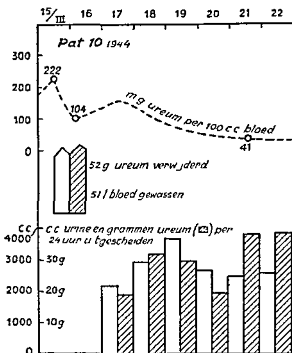


Fig 49
Graph of patient no 10 a man of 50 years with an anuria after using sulfapyridine

Three weeks before coming in for treatment he developed a pneumonia which was treated with sulphamethylthiazole, and a week before coming in he got a recurrence of his pneumonia which this time was treated with sulphapyridine Anuria followed

After four days the blood urea had risen to 222 mgr per 100 cc the patient had apart from his fibrillation and his dilated heart a continuous hiccough He was connected with the artificial kidney without delay 52 grams of urea were removed blood urea sank to 104 mg per 100 cc

After one day's rest a cystoscopy was performed and the pelves were washed out Immediately after this the diuresis started The patient recovered

As a rule the first thing to be done is to have a cystoscopy performed when dealing with an anuria after the use of chemotherapeutics In the case of patient no 14, where the chemotherapy might have been the cause of the anuria I consequently had that done first

Not always, however is the cystoscopy followed by the desired result, i e by diuresis while after a cystoscopy one must wait till



F g 50
Roentgenogram of the chest of patient no 10
Heart enlarged speciall, to the right Pneumonia on
the right side not yet cleared up

51 grams of urea were removed, and the blood urea fell from 278 to 162 mg per 100 cc Dialysis was discontinued owing to the extremely bad condition of the patient, and she died soon afterwards

(Patient no 21) Man of 74 Under the care of Dr GEELEN in Dr ENNEKING's ward at Nijmegen Prostatectomy ten years ago Dysuria and incontinence during the last four years Four months ago multiple vesical calculi removed by operation Three weeks ago symptoms of pyelo cystitis began, fever, almost continual hiccough and pain in the back Admitted 7 6-46 The prostate gland was found to have enlarged again and on x ray the shadow of a stone was seen at the right pelvo ureteric junction Blood pressure 115/75 Blood urea 320 mg %, plasma NaCl 660 mg % Patient seemed moderately dehydrated Dialysis was started next day, but owing to the arterial cannula having too small an aperture the flow through the artificial kidney was slow and only 33 grams urea were removed in 7 hours The blood urea fell to 203 mg per 100 cc After dialysis the patient was very tired and slightly icteric but his general condition was not bad and diuresis set in Six weeks later he went home relatively well (fig 51)

(Patient no 22) Man of 68 He had an indwelling catheter on account of prostatic hypertrophy for 4 to 5 months Subsequent prostatectomy with a progressive post-operative rise in bloodurea and deterioration of his general condition Admitted to Kampen sixteen days after operation with pronounced CHEYNE STOKES breathing, blood urea of 309 mg % and alkalireserve 28 vols % Dialysis removed 66 grams of urea the blood urea fell to 82, and the alkalireserve rose to 44 The cardiac condition however remained very bad, and two days later he died of cardiac failure and pulmonary congestion

Post mortem, congenitally atrophic left kidney, marked hydronephrosis with infection and scarring of the right kidney

In patient 20 a blood urea of 278 mg per 100 cc suggested that uraemia was not the cause of her uncosciousness. Dialysis was nevertheless performed at the request of the neurologist and for the training of the "artificial kidney staff", as it seemed that nothing would be lost

Had patient 22 come in ten days earlier, it might have been possible to return his blood chemistry to the same position as it was at the end of five months of indwelling catheter

The recovery of patient 21, a man of 74, shows that age in itself need not be a contraindication to using the artificial kidney This man's improvement after treatment by dialysis will have been only partly due to the removal of retention products, and probably more to correction of extrarenal factors present at the time It is quite possible that a similar improvement could have been obtained by intravenous infusions alone In face of the result, however, no regret need be entertained that he was treated with the artificial kidney

Our impression is that the kidney function of patients wih prostatic hypertrophy, calculi or other forms of renal obstruction, is regained once the obstruction is removed The artificial kidney may help to tide over a difficult period

CHAPTER V

THE CLINICAL SYMPTOMS OF URAEMIA DURING AND AFTER THE DIALYSIS

As some "pressor" substances, which seem to play a part in many forms of raised blood-pressure are dialysable one might expect a lowering of the blood-pressure by dialysis in case of hypertension caused by renal ischaemia However it seems unlikely to me that any influence can be exercised on the angiopasms of acute glomerulo nephritis by dialysis (literature no 7, 15)

Our first patient, the only one of our series of patients, who may have had this pressorsubstance in a considerable degree in her blood, showed a fall in bloodpressure after each dialysis, clearly to be seen in curve 34 on p 39 It is highly probable that these falls must be conceived as a more or less prolongated shock, but the clinical aspect was difficult to ascertain

The fall in bloodpressure which appeared in other patients during dialysis, must certainly be conceived as a symptom of shock This will be discussed in the chapter about reaction of the patient during dialysis

The ocular symptoms

The ocular symptoms in chronic nephritis depend more on hypertension than on uraemia In the first patient with contracted kid neys (patient no 1) we treated, a striking improvement of the fundi and the vision appeared Both are either accidental or due to the decline in hypertension during this period

It would be interesting to know if the white foci in the fundus oculi improve after dialysis This was temporarily the case with patient no 1

The mental condition

Several patients were comatose and dying when they were connected with the kidney They did not regain consciousness during treatment Some of the patients who were praecomatose became fully concious

Patient no 5 awoke during the dialysis, and spoke more clearly with his relations than he had done for days.

Patient no 6 regained consciousness in the night while she was on the kidney, and she began to talk about her relations, so that

I had morphine administered to her to make her sleep again

Patient no 11 who was very sleepy, improved much after the dialysis in that respect

Patient no 1 never made that stuporose and indolent impression which we mostly see in uraemic patients

Patient no 14, no 15 and 18 remained fully conscious till shortly before their death It cannot be assumed that this would have been possible without dialysis

Patient no 17 in a stuporose condition had her mind completely *cleared after dialysis*

Vomiting

Some patients vomited, but in the first 15 patients we had no case where vomiting was so desperate after a dialysis as we formerly often saw in uraemia [1])

TABLE 1

in which is tabulated the improvement or deterioration of the diuresis after dialysis

Patient	died too early to form an opinion	Diuresis after treatment				Remarks
		Set going	Improved	Remained equal	Declined	
1					+	
2			+			
3	+					
4		+				Ureter got loose from sigmoid Urine in the peritoneum
5	+					700 cc of urine in the bladder
6		+				
7			·			
8	+					No kidney left
9		+				Much blood in urine
10		+				After cystoscopy
11					+	
12	+					Much blood in urine Hb 30%
13				+		Quantities hard to estimate
14	+					
15		+				

[1]) The 18th patient has vomited much during and after dialysis We have investigated if the high bloodsugar played a part but no evidence was found.

The diuresis

From the curve on p 39 one gets the impression that the urine production of our first patient became less after the greater dialyses We have ascribed this to the temporarily reduced blood pressure (or to shock if one likes), and to the steady aggravation of the contraction of the kidney At any rate we thought it desirable to investigate in the following 15 patients if the dialysis could have an unfavourable influence on the diuresis

The above table shows that in 6 patients the diuresis has been improved or set going while it has only decreased in the case of 2 patients (our first patient included), presumably because the high blood pressure was no longer maintained

Uraemic exanthema

Patient no 13 and patient no 25 showed a very clearly papilliform and blotched exanthema After dialysis it disappeared within a few days

CHAPTER VI

REACTIONS OF THE PATIENT DURING DIALYSIS AND THEIR THERAPY.

Rigors.

We are doing our utmost to prevent rigors, yet on 29 consecutive dialyses 8 occurred

We tried to prevent rigors by cleaning the tubes and all the material coming into contact with blood as carefully as the tubes used for a blood-transfusion

Some rigors have been caused by heparin Others have arisen from the use of liquids given intravenously during dialysis which were not so pyrogen free as the manufacturer hoped

Shock.

When too much blood is allowed to run from the patient into the kidney, the patient will develop a clinical condition generally described as shock He will recover when the blood is led back at once, or when a bloodtransfusion is given

If shock is repeated several times the patient does not recover completely, it may take hours, sometimes days before the blood pressure reaches its former level again

There are, however, conditions very similar to the clinical picture of shock that are not due to or not entirely due to loss of blood

Peripheral venous construction may occur It may herald the unset of a rigor, it may be due to heartfailure, in which case therapy must be different The patients often showed the clinical picture of shock before dialysis started, especially when they were dehydrated If the venous pressure was not raised and the heart was not thought to be the primary reason of the condition, the shock could sometimes be improved by giving bloodtransfusions during dialysis

A very good example of this we saw in patient no 6

The blood pressure at the beginning of the dialysis was 130/85 at the end 170/80 This seems too high at first glance, but in a woman

of 100 kilos and with an acute glomerulo nephritis one may expect a similar blood pressure and then the blood pressure 130 85 must be taken as too low

Therapy

Shock should be treated at once and effectually Salinesolutions given into the bloodstream tend to leave it immediately again The longer a shock exists the more it is necessary to fight it with colloidal solutions blood bloodplasma capain In a patient who has a disposition to shock the ½ to ¾ L of blood necessary to fill the kidney must be replaced at once In these mostly seriously ill patients one must always hover between shock and overloading of the circulation with as its most serious consequence pulmonary oedema Occasionally we gave medicaments to fight shock but I never got the impression that they were of any use in serious cases No more have I seen any evidence of the value of remedies for the heart digitalis preparations ouabaine etc for the treatment of the acute failure in these patients

Pulmonary oedema

Patients with uraemia run a greater risk of pulmonary edema than others they often have oedema and often hypertension so a disposition towards left failure pulmonary congestion pulmonary oedema. Strong anaemia and aspiration pneumonias which may occur as the patients are often semicomatose and may vomit further increase the chance of pulmonary oedema The same holds good if a deficit of salt is calculated in a patient and the calculated quantity is administered too quickly This should be done carefully in the course of a few days

When one fights a shock one is compelled to supply big quantities of fluid intravenously in a short time If too much saline solution or 5 % of glucose is used or if it is given too quickly then one runs great risk of failure the shock continues and pulmonary edema appears One should use for this purpose blood bloodplasma or an equivalent substitute in these patients

Therapy

When pulmonary oedema appears or one is afraid of pulmonary oedema owing to much bronchial and pulmonary congestion then immediately a large venesection must be done i e 500—1000 cc of blood If it happens during dialysis one may add extra glucose to the bathwater by which fluid is drawn from the blood (and out of the tissues) into the bathwater Moreover 10 or 20 mgrs of morphine are given. Theophylline may be tried

Restlessness of the patient and its treatment with narcotics.

Uraemic patients may be desorientated and restless Since we fix glass canulae into the bloodvessels of the patient, and after that bandage the whole arm, we need no longer be so afraid of any restlessness of the patient, as when we were working with venepunctures

My impression is that patients with uraemia sometimes reacted badly to the high dose of morphine which we injected formerly We shall have to be as economical as possible with narcotics in future

Factors which promoted or caused death

When we know with what symptoms "the patients to whom an artificial kidney is applied" die, and what factors contributed towards death, then we may perhaps postpone or prevent the end by *minimising these factors*

For this purpose the gloomy Table 2 is given on p 64 We see pulmonary oedema 8 times and bronchopneumonia 4 times

In some of the subsequent patients it has been possible to reduce pulmonary oedema with which they were admitted It should be realised that uraemic patients usually die from pulmonary oedema and that the artificial kidney cannot be held responsible for these deaths Not only can we reduce the pulmonary oedema by dialysis but we can now also fight bronchopneumonia with penicilline

TABLE 2

Patient No	Factors which promoted or caused death
1	Uraemia
2	Dehydration, acidosis
3	Coma after collapse caused by acute insufficientia cordis
4	Shock, Urine in the abdominal cavity, Ca with metastases
6	Bronchopneumonia and pulmonary edema
7	Delirium Sepsis (of which the kidneycarbuncle was only a part)
8	Coma and pulmonary edema
9	? (no pulmonary edema) Ca with metastases
10	Cured
11	Pulmonary edema after distinct left insufficiency
12	Pulmonary edema and bronchopneumonia
13	Pulmonary edema, haematothorax and pneumothorax
14	Dehydration Pneumonia
15	Haemorrhage Shock, Coma Pulmonary edema

*

CHAPTER VII

INVESTIGATION ON SUBSTANCES WHICH WERE REMOVED (OR SUPPLIED) BY THE DIALYSIS WITH THE ARTIFICIAL KIDNEY.

Non-protein nitrogen

Whether a substance is dialysable or not depends inter alea on the size of its molecule and whether it is bound to the plasma proteins

TABLE 3

The rest nitrogen of the blood, expressed in mgrs per 100 cc before and after dialysis

Patient and dialysis	Rest N of blood of patient before the dialysis	Id after dialysis	Rest N of blood from kidney
1 x *)	188		49
8	340	after 13 l 280	
10	142	91	54

It is clear that the restnitrogen of the blood falls by dialysis. We have further given up determinations of restnitrogen, and ther determined its separate components

Urea.

Normal quantity in the blood 15—50 mgrs per 100 cc

the urine per 24 hours

*) Patient no 1, dialysis no X of this patient

TABLE 5

The urea of the blood, expressed in mgrs per 100 cc, before and after having flowed once through the kidney

Patient and dialysis	Urea of the blood before going into the kidney	Urea of the blood after it has flowed once through the kidney
5 I	238	30
7 I	142	47
7 II	89	71
13 I	± 600	134

The height of the urea in the blood issuing from the kidney especially depends on the concentration of the urea in the bath water, and consequently on the question whether the bathwater has just been refreshed or not. Thus the concentrations of the bath water before it was refreshed, amounted to

TABLE 6

Urea amount of bathwater expressed in mgrs per 100 cc before it was refreshed (this is mostly after 2 or 3 hours of dialysis)

Patient and dialysis	1st bath	2nd bath	3rd bath
13 I	106	81	50
13 II	35	50	
14 I	25	51	35
15 I	49	22	

The success of the artificial kidney would be higher, if we had a reservoir with rinsingwater, flowing in the opposite direction of the bloodcurrent at our disposal instead of one bath of 100 Ls

TABLE 7

The total quantities of urea which could be shown per dialysis in the bathwater

Patient and dialysis	10	11	12	13 I	13 II	14	15 I	15 II
Quantity of urea in grams removed per dialysis	52	146	65	263	95	102	71	50

The blood which has been purified to a large extent of urea and other retention-products in the kidney, comes back into the cir

culation of the patient, and is again directly provided with retention-products from all tissuefluids Indeed it takes some time before one begins to perceive some sign of a fall of the retention-products in the blood of the patient.

In the table below the urea amount of the patient's blood before and after dialysis is compared for 10 patients

The samples have been taken from the tube, as close as possible to the arteria radialis

TABLE 8

Urea of the blood of the patient before and after dialysis

Patient and dialysis	12	13 I	13 II	14	15	15 II
Blood of patient before dialysis	263	704	386	648	389	375
Blood of patient after dialysis	69	192	187	263	159	228

The greatest fall of the urea of the blood was 512 mgrs per 100 cc

But not only urea, also other retention products are removed rom the blood by the artificial kidney

reatinin

Normal concentration in the bloodplasma 0,7 to 2 mg per 100 cc
Normal excretion with the urine per 24 hours 1,1—1,5 g

TABLE 9

The excretion of creatinin by the artificial kidney, expressed in mgrs per 100 cc

Patient and dialysis	Blood of patient before the dialysis	Blood of patient after the dialysis	Blood from the kidney
1 x	5,4	4,7	2,3
5	1,8	1,7	1,2
7 I	4 6	2,5	1,6
7 II	3,4	1,4	1,0
9	7	2,2	1,2
12	6,1	2,9	2,9
13 I	7	2,9	2,1
14	4,2	3,1	2

It appears from table 9 that the creatinin of the bloodplasma of a patient with uraemia may be exceedingly reduced by an extensive dialysis, if continued for a considerable time, it may be brought back within normal bounds.

Uric acid

Normal content of uric acid of the bloodplasma 2—4,5 mg, per 100 cc
Normal excretion with the urine per 24 hours 0,4—1 g

TABLE 10

The excretion of uric acid by the artificial kidney
Uric acid expressed in mgrs per 100 cc

Patient and dialysis	Blood of patient	Ibid after dialysis	Blood from the kidney	Bathwater
1x	9 7	4 7	2 3	
3	14 9	8 6	5 7	1 2
5	7,1	5 2	3 5	
6	10 2	5 8	5 3	
7	8	5 3		
8	9 4	8		0 63
11	8 8	5 2		
13 i	11	5	3	
ii	7,4		4 6	
14	20	24,7 [1])	3 8	

Just as with the urea, it is clearly shown that the dialysis is most effective if the concentration of the uric acid in the blood is high

Indoxyl

Normally the blood contains only 0 026 to 0,85 mgrs per 100 cc plasma. In uraemia one would find up to 7 mgrs of indoxyl per 100 c of bloodplasma

TABLE 11

Indoxyl of the bloodplasma expressed in mgrs per 100 cc

Patient	Blood of patient before dialysis	Ibid after dialysis	Blood from the kidney	Bathwate
3	+	+	trace	
6	0,4		0 2	trace

HAAS showed that indoxyl can be removed from dogs by dialysi
We had no further reason to doubt this, and therefore did n
perform further determinations

Substances, causing the xanthoprotein-reaction

The normal xanthoprotein reaction is 15—30 % of the standard B

[1]) Agonal increase of uric acid

the bloodserum of patients with uraemia can give These substances are probably bound to the plasma albumen but it is questionable how firm this connection is

For a great part of the above-mentioned substances it has been proved by ABEL, ROWNTREE and TURNER that they can be removed from the blood by dialysis with celloidinmembranes One would expect that the xanthoprotein-reaction would become lower after a successful dialysis However it does not always prove possible to read accurately the colour-reaction in plasma of heparinised blood On the whole our impression was that the xanthoprotein decreased by the dialysis

Minerals

Something has already been stated in this respect in Chapter III when discussing the bath water In the very large dialyses the concentration of several minerals in the blood plasma (to be exact the plasma-water) followed the concentration of the same substances in the bath water more and more Finally these two concentrations would become equal to each other (at least in so far as the minerals concerned are dissociated in the bloodplasma calcium for example is only dissociated for 50) Minerals may be extracted from the patient by leaving them out of the bath water Minerals may be supplied t the p tien by adding them to the bathwater

In so far as they might be of importance the different minerals are discussed below

Sodium.

The normal sodium percentage of the blood serum i 3_0 350 mgr per .00 ccm While the chloride content of the bloodplasma tends to be lowered in uraemia, this is usually not the ca with the sodium content

TABLE 12

Sodium of the patient s bloodplasma in mgr per 100 ccm

Patient and dialysis	Before the dialysis	After the dialysis	Blood from the kidney	Remarks
1	311	320	[illegible]	Remained normal
VII	305	267	[illegible]	Lowered but not enough
5	(371)		311	Become too high?
7	(293)	334	[illegible]	Normalised
13 I	321	309	31	Normalised
11	376	331	310	Remained normal Bath 300 mgr Na per 100cc
14	374	327		
15 I	(342) (339) 322			

The values between ( ) were determined some days previously

In none of our patients the sodium percentage had been lowered greatly. If sodium is retained fluid is held in the body outside the cells as well, and this means edema Therefore we are afraid of supplying sodium Certainly if the patient already has edema and the more so as in all these patients an overloading of the left side of the heart with pulmonary edema is imminent

Potassium

The normal potassium level of the bloodserum is 16—20 mgr per [illegible]

Repeatedly a strong rise of the potassium content of the bloodserum is noticed in patients with uraemia shortly before death

It is mostly impossible to determine the potassium percentage of the heparinised bloodplasma We cannot therefore determine the potassium content of the bloodserum during and after the dialysis, as long as the patient is still under the influence of the heparinisation Therefore we must be content with the potassium level some days after the dialysis in the table below, and try to draw our conclusions from these

TABLE 13

Potassium content of the patient's bloodserum, expressed in mgr per 100 cc

Patient	Potassium of blood serum before the dialysis	ibid some days after the dialysis	idem later	Potassium demonstrated in the bathwater (later on it has been added to it)
1	19,4	18	88 (8 hrs post mortem)	3 4 mgr per 100 ccm
2	22 2			
3	37			
6		17 5		7,2 mgr per 100 ccm
7	33	27 3	27 3	
9	27			
10	23 5			
13	21,5	14,8	25 6	
15	14,8, 17,6, 19		20 7	
17	55	19		

Noting the potassium of patients nos 7 and 13 after dialysis it becomes very likely that potassium is removed by the dialysis, in patient no 13 to such a degree, that it appeared desirable to add potassium to the bath water henceforth, to prevent a too strong decline

[Calci]um.

The normal calcium of the blood serum is 9—11 mgr per 100 ccm Data concerning phosphate are to be found on page 73 The calcium in the blood plasma is $^1/_2$ to $^2/_3$ free i e in diffusable state If the percentage of free calcium falls through dialysis the calcium albumen dissociates again to a larger extent so that it would be possible to remove finally all the calcium by dialysis We have determined the total content of calcium, but especially the calcium i n is of importance for the appearance or absence of tetany

TABLE 14

Calcium and phosphate of the blood plasma expressed in mgr per 100 cc

Patient and dialysis	Before dialysis: Calcium	Before dialysis: Phosphate expressed as P	After dialysis: Calcium	After dialysis: Phosphate expressed as P	Blood from the kidney: Calcium	Blood from the kidney: Phosphate expressed as P
—	9 4		8		4	
1 x			10		5	
5	10,2		6 2		4	
6	9 5		6 9	14 1		
11	6,8	8,8	7 5		5	
"	9 3	13,2	9 5		4	3 1
8		7,6	5 1			
9	16	7,8	later 8		3	
12	12,3	15	later 6 0			
13	7 5	11	5			
"	(8 7)	9				
14	6					

The table shows that the calcium usually was about normal in the patients where it was determined occasionally it was lowered some times raised! The calcium of the patient s blood has mostly been lowered by the dialysis sometimes to 5 mgr per 100 cc Tetany we never noticed[1]) Neither did the uraemic twitchings become more serious during dialysis Sometimes they improved perhaps [f]ollowing the administration of calcium gluconate intravenously

In the chapter concerning the bath water it has already been stated that no $CaCl_2$ is to be added to the bath already containing $NaHCO_3$ Therefore we inject calcium gluconate intravenously (i e into the tube!)

Magnesium

This is normally present in the blood plasma to an amount of 2,3 to 4 mgr per 100 ccm, and 60—90 % of this is diffusible

It was thought that the magnesium would not be raised in uraemia BROOKFIELD (lit. no 22), however is of opinion that in uraemia the magnesium content may certainly have been raised especially if sulphate of magnesium has been administered to the patient as a laxa-

[1]) Note at the correction We saw two cases now with low bloodcalcium before dialysis showing convulsions with some tetanic caracteristics Giving alkali to such patients may reduce the ionized calcium and cause tetania

tive. In exceptional cases the magnesium content should even be able [illegible] effect may become apparent Even if

Chloride

The chloride percentage is nearly always given as NaCl percentage [illegible] 340—380 mgr per 100 ccm

[illegible] n the [illegible] ating, sweating and diarrhoea, partly also by the fact that defective kidneys *when they are still producing urine, can only do so by excreting chloride* as well, however acute the shortage in the body may be Moreover these patients as a rule take up very little or no chloride with their food

If one corrects a chloride shortage of the blood plasma, one supplies chloride *mainly in the shape of* NaCl *Not always, however,* does a patient react favourably on a too rapid correction of his NaCl[1] *The possibility of pulmonary edema should always be kept in mind*

TABLE 16

Cl of the patient's bloodplasma, expressed as NaCl in mgr per 100 ccm

Patient and dialysis	NaCl before dialysis	NaCl after dialysis	NaCl percentage of the bath	Remarks
2	584	642	700	become too high
3	619	653	700	" " "
5	750	?	650	duly fallen?
			700	patient was exsiccated
6	515	683	700	become too high
7 I	521	536	650	risen somewhat, *but not yet* normal
II	508	605	650	normalised
9	545	626	650	"
10	526	598	650	"
11	551	604	700	"
12				
13 I				
II				
14				
15 I				
II				

This table very clearly shows that the NaCl of the blood plasma parallels the bathwater[1] So it is of great importance to choose *the Cl-ion concentration in the bathwater well; both a shortage* and

[1]) See FISHBERG (litt no 5)

a surplus are corrected. When comparing the amount of neg ions (Cl', HCO_3') in plasma and bathwater the DONNAN-equilibrium should be considered because within the membranes indiffusible neg ions (albumen) are found By this the Cl and HCO_3-amount of the bathwater is 10—20 % higher than that of the plasma when in equilibrium Moreover the NaCl amounts of the bloodplasma have been expressed per 100 cc of plasma while actually the percentage of the plasma water is concerned which lies about 10 % higher

Phosphate

In the inorganic form phosphorus occurs in the blood as H_2PO_4 and HPO_4''

The phosphate is expressed as phosphorus Normal phosphate of the bloodplasma 2—4 mgrs per 100 cc For children 4 6 mgr per 100 cc

In patients with uraemia nearly always an increase of the phosphate is found In table 14 the phosphate at the beginning of the dialysis varies between 7,8 and 15 mgr per 100 cc Phosphate is quickly removed by the dialysis

Alkali reserve

The normal alkali reserve amounts [illegible] CO_2 The CO_2 which is made free at the determination of the alkali reserve comes for the greater part from the NaHCO (sodium bicarbonate) of the blood plasma 1 vol % CO_2 corresponds with [illegible] mgr $NaHCO_3$

TABLE 17

Alkali reserve in % volume of the blood of the patient

Patient	Before dialysis	After dialysis	Blood from the kidney	Later	Bath Na HCO_3
7 I	37	41			300 mgr % 63 % vol CO_2
[illegible]	31	(3?) (41) 40	[illegible]4		
8	30				
10	48	5?	44		
13	39	52	[illegible]		
15 I	[illegible]	[illegible]	[illegible]4		[illegible]00 mgr (31 vol %[1])
16	40	47			
17	40	4[illegible]	53		
18	[illegible]	42	41		
19	38	47		51	
[illegible]	[illegible]	44			
23	19	33	42	50	
24	37	43		4	
25	[illegible]		40	49	

[1]) Determination of the alkali reserve of the bathwater after the dialysis

From the above table it is seen that the patients mostly have a moderately reduced alkali reserve in the beginning which is improved after dialysis

In dialysis 7II and in dialysis 13 the patient's alkali-reserve is higher (better) after the dialysis than before No extra $NaHCO_3$ was given intravenously Presumably retained acids have been *removed by the dialysis The blood from the kidney had a lower* alkali-reserve (24 resp 27 vol %) than the patient's blood One may take into account that the CO_2 dissolved in the blood, which is included in the determination of the alkali-reserve, will have escaped through the cellophane during the dialysis, this however only makes a difference of about 3 vol % Only twice a determination has been performed of the alkali reserve of the bathwater after dialysis With the 15th patient the alkali reserve of the bath water after the first dialysis was only 31 vol % (in the beginning 53 vol % is to be expected) This would indicate that large quantities of acid left the patient s blood for the bathwater, and that there they expelled the CO_2 from the $NaHCO_3$

It is necessary that more determinations are performed and if this single observation should be confirmed we need not be surprised at the low values of the alkali reserve of the blood from the kidney

Extra $NaHCO_3$ might be added to the bathwater during dialysis but then a rather high sodium concentration is obtained

We have been afraid that a high percentage of $NaHCO_3$ and a strongly alkaline bathwater would influence the pH of the blood with possibly unfavourable results If oxygen with 5 % CO_2 were bubbled up through the bathwater continually, the desired pH would be obtained

To perform this one would have to make a cellophane hood over the kidney to provide the air inside this hood with 5 % CO_2 The 5 % CO_2 would be mixed very intensely with the bathwater by the rotating cylinder An additional advantage of a bathwater with a correct pH would be that one could add calciumchloride to the bath water without the calcium being precipitated as calciumcarbonate

As long as we do not possess a cellophane hood over the artificial kidney, and do not have CO_2 bubbling through the bathwater, we repeatedly give small quantities of $NaHCO_3$, 5 %, diluted with saline intravenously to patients who are connected with the artificial kidney in a state of strong acidosis The alkali reserve must be checked to see whether enough has been given[1])

---

[1]) Calciumgluconate should be given at the same time otherwise tetania may be provoked

Glucose

Normal percentage of glucose of the blood (or the blood plasma) 70—130 mgr per 100 ccm After a meal up to 160

TABLE 18

Glucose in mgr per 100 ccm in the blood and in the bath water in the case of patient no 1

Dialysis No	IV	V	VII	X
Blood of patient before dialysis		1	114 114	104 106
Blood from kidney after dialysis		[illegible]	4[illegible]0 4[illegible]4	5[illegible]0 [illegible]63
Bath water			+ 1[illegible]00	± 1500
Blood from patient after dialysis		[illegible]	[illegible]01 [illegible]01	189 [illegible]00
	Bath water without glucose		Bath water with glucose	

As is to be seen from the table above in our first patient the glucose of the blood from the kidney proved to fall very strongly if no glucose was added to the bathwater After that we added 1 % glucose to the bathwater to prevent the haemolysis of the blood in the kidney

TABLE 19

Glucose of the blood in mgr per 100 ccm

Patient and dialysis	Blood before the dialysis	Blood after the dialyse	Blood from the kidney	Bath
3	18[illegible]	3[illegible]1	[illegible]	1500
5		434	[illegible]	1500
7	10[illegible]	63	01	1500
8	144	3[illegible]9		1500
9	84	[illegible]08	31	1500
13		45[illegible]		1500

Later we added still more glucose (3 %) to the bathwater in order to draw oedema fluid towards the bathwater by osmotic force. We received the impression that with a bath glucose content of 1½ % even in the larger dialysis the patient's bloodsugar did not become very much higher than 535 mgr per 100 ccm We do not believe this carries with it any disadvantage for the patient The glucose will probably be consumed gratefully

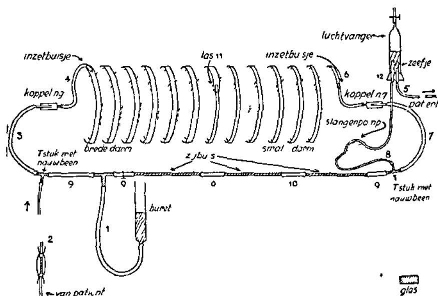
INSTRUCTIONS FOR FITTING UP AND CLEANING THE ARTIFICIAL KIDNEY.

For each dialysis the following are required:

I A packet of tubing, previously sterilized in autoclave, and packed in a sterile condition (tubes, glass vessels and couplings may also be boiled before dialysis)

Contents of the parcel of tubing

The wide tubes have a diameter of 6 mms inner section and 11 mms outer section The narrow ones have a diameter of 4 mms inner, and 7,5 mms outer section *The numbers in front of the tubes refer to the fitting up diagram A*

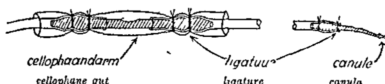


Fitting up Diagam A

inzetbuisje = insertion tube
koppeling = coupling
T-stuk met nauwbeen =
T piece with one narrow end
breede darm =
wide cellophane tube
van patient = from patient

las = joint
luchtvanger = air catcher
zeefje = sieve
slangenpomp = tube-pump
zijbuis = side tube
smalle darm =
narrow cellophane tube

THE PRESSURE WINDOW OF THE OUTFLOW-TUBE FROM THE PATIENT



cellophane gut *ligature* *canula*

Sketch B

1 a wide tube, about 125 cms long for the burette
2. a narrow tube, 170 cms long, with pressure-window (see Sketch B)
3 wide tube, 50 cms long (T-piece to coupling)
4 a wide tube, 60 cms long, with a glass insertion piece (coupling to gut)
5 a narrow tube, 150 cms long, finishing in a small glass tube close to the end the return-tube to the patient (This latter piece of tubing is used when tapping samples of blood, the tube is pricked with a needle and the blood sucked up by means of a syringe)
6 a wide tube, 60 cms long, with a glass insertion piece (gut to coupling)
7 a wide tube, 50 cms long (coupling to T piece)
8. a narrow tube, 45 cms long (running through the tube-pump to the air-catcher)
9 and 10 five wide tubes of about 10 cms in length, connecting-pieces between the glass T-pieces and the glass parts of the side-tube
11 a couple of joints (glass tubing covered with rubber)
12 the rubber stop of the air-catcher, with inlet tube and filter
13 two glass T-pieces, with one arm tapering and a normal T-piece
14 the couplings
15 the wooden reel upon which are wound either 10 ms of narrow and 30 m of wider, or 45 m of narrow cellophane gut
16 two packings (cotton threads of 12 cms)
17 one or two artery forceps (to be placed on top so as to be immediately accessible)

II A parcel of larger glass vessels, either dry sterilized or boiled.

Contents of the parcel of larger glass vessels

1 a burette with a pierced cork
2. an air-catcher, with a small rubber tube of about 3 cms on its spout

3 the side-tube, in 3 parts of 30 cms in length each, outer section 9 mms

III Sterile canulae

A collection of glass canulae for the veins and arteries should be present, each of them packed sterile in a test-tube closed with cottonwool, to two canulae a 10 cm piece of rubber tubing with a glass stopper is connected fig 32a

IV 15 litres of sterile, apyrogenic saline, at least 1½ litres of blood compatible to the patient, or (blood)plasma, while between 2 and 3 litres of blood should be available at short notice

Preparation of apyrogenic salt solution

The saline solution is prepared in special enamel vessels with a capacity of about 8 litres The vessels are brushed out with a hot soda solution, and repeatedly rinsed with hot water They are finally rinsed three times either with fresh tapwater or with fresh apyrogenic water After this the vessels are filled with fresh apyrogenic distilled water or fresh tapwater, to which 9 g of NaCl per litre is then added

A piece of gauze is stretched across the opening of the vessel, and over this a piece of taffeta Of this, a slip should be left free at the spout to allow steam to escape during boiling, each vessel being allowed to boil for at least a quarter of an hour The taffeta is then tied so as to close the vessel the latter being cooled in a bath of cold water

V Medicaments, instruments and spare accessories

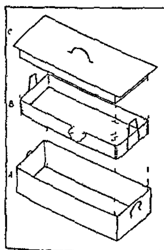
See that the following are available

1 Heparin (maximum of 1000 to 2000 mg for each time)
2 Ready-weighed quantities of salt for renewing the bath water, for a bath of 100 L 600 grs of NaCl, 200 grs of $NaHCO_3$, 40 grs of KCl, and 1500 or 2000 grs of glucose
3 Cottonwool, ether and alcohol, plaster, scissors, sterile syringes, and a collection of long and short needles.
4 Spare glass T-pieces, links, joints, glass stops to shut off tubes, all kept sterile in alcohol
5 Thread to fasten ligatures, piece of elastic, talcum, grease oil, screw-driver and pliers
6 A rack provided with both sterile and non-sterile test-tubes and one provided with tubes containing sodium oxalate and paraffin, for samples for determining the alkali reserve Labels should not be forgotten!

7 A number of bottles of 100 and 300 cm³ with glass funnels for samples of the bath water
8 Lists to enter observations and samples
9 A spare driving belt for the motor
10 Earth wires both of the heating element and the motor should be checked

Fitting up and making ready for use

The tubes glass work etc may be sterilized in the autoclave and kept in a dry sterile condition In this case the extremities of the tubes must be moistened with alcohol in order to ensure their being easily fixed to the glass parts and couplings The tubes and the glass work may also be boiled in a large pan (see Sketch C) immediately before dialysis



Sketch C
Measures A (inside)
Length, 53 cm Width 30 5 cm
Height 12 5 cm
Height B 5 cms
Underneath B 4 *small legs* 0 8 cm in height

The cellophane gut is wound on a wooden reel (fig 30) and boiled for a quarter of an hour in the pan with plenty of water in order to remove as far as possible the glycerine in which it was soaked

Fitting the couplings

Take the inner tube in the hand holding it by the protruding cross piece and push the screw-cap on it against the cross piece

The counternut should be turned on to the wider tube first

Soak a sterile cotton thread 12 cms long in a pot of sterile vaseline and wind this thread with the aid of a sterile forceps around the inner tube Then push the screw cap as far as possible over the packing and push the inner tube into the wider one The screw cap may now be turned on without any risk of the fibres of the cotton thread blocking op the screw thread

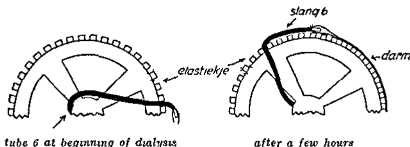
Push the tube with the glass inset piece on to the wider tube (No. 4) and introduce this tube through the hollow axis of the kidney The coupling is then fixed by means of a screw Fix the free extremity of the coupling with a wire or a brace In the same way the second coupling is fixed in the hollow axis at the other end of the cylinder Do not forget the driving belt!

The cellophane gut

The rubber tube (No 4) with the little glass tube inserted in the end of it is now led outside through the spokes of the wheel and passed between the laths to the outside of the cylinder The end of the tube is wiped off with alcohol, the beginning of the cellophane gut is pushed on to it and fixed with two ligatures over the rubber tube with the glass insertion-piece After this the gut is wound tightly around the cylinder Be careful not to let the windings overlap, they should lie closely side by side

When the first length of gut has been wound upon the cylinder, a second length is attached to the first by means of a joint (No 11) Both guts have to be fixed round the rubber piece with a double ligature The second length of gut is then also wound on the cylinder, and its extremity connected with the tube (No 6), which at that point, protrudes through the other hollow axis of the cylinder This tube may have to be lengthened by nearly half the circumference of the cylinder so that the cellophane gut may be tightened when after some hours of dialysis it has stretched (see Sketch D)

THE SHIFTING OF THE TUBE 6 DURING DIALYSIS



tube 6 at beginning of dialysis *after a few hours*

Sketch D

The figure on the left is not quite correct, inasmuch as the tube 6 will always have to run a little way over the outside of the roll before it is fixed to the cellophane gut Elastiekje = elastic band

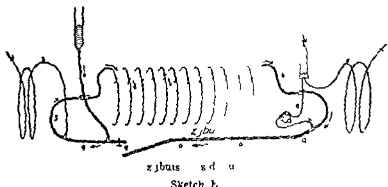
The way the remaining part of the circuit is mounted follows from the Sketch A The tube which is led through the tube pump must be rubbed with plenty of talcum beforehand in order to obviate any damage by the rolling of the pump

Rinsing

When the tubes are fixed, about 10 litres of sterile, apyrogenic salt solution, in portions of 400 cm³, are let in via the burette and allowed to pass through the tubes and the gut, the circuit should

be temporarily interrupted in the side tube (see Sketch E) See to it that the air-catcher and both in and outflow tubes are rinsed then close these tubes with a clamp and protect the open extrem t es either in sterile tubes or with sterile gauze

THE CIRCUIT INTERRUPTED DURIN I INSIN



Sketch E

After making sure that there are no le k n the gut about half litre of salt solution with 400 mgs of heparine is poured into e burette This is allowed to c rculate Ster le glass canulae are en fixed on both outflow and return tub s after which these ssages are also rinsed with the salt solut n and heparine care ng taken that as little as possible of th prec o heparine is ilt.

akages

When the kidney has been sufficiently rinsed the cellophane it is carefully tested for leakage If necessary the frame with e rotating-cylinder of the kidney is raised in order to examine nditions underneath the cylinder (see fig 19) A leak may some nes be localized by binding off the gut at different points with tape The liquid then accumulates in the windings in front of e stricture When a leak is found the cellophane gut is cut rough at the point where the opening is and a joint is made need be one may also remove a length of gut a little shorter an one winding and connect the remaining ends with a joint e a bit of rubber tubing with a small glass tube inside for tmness)

Double ligatures should be placed everywhere round the cello hane gut When the cellophane gets wet it very easily slips from der a thread and therefore the thread should be wound round e cellophane gut as many as 10 or 12 times

SUMMARY OF PART I ARTIFICIAL KIDNEY.

As early as 1913 ABEL ROWNTREE and TURNER were able to remove products of katabolism from the blood of experimental animals by means of dialysis The blood is prevented from clotting and flows outside the body through a system of dialysing tubes The substances with small molecules to which nearly all the products excreted with normal urine belong, can be removed by dialysis, whereas large molecules such as proteins cannot pass through the membrane

In spite of some later efforts, vivi-dialysis has not found a lasting place in clinical use At present we have greater opportunities than earlier workers, because we have excellent dialysing-membranes (cellophane) and a reliable non toxic anticoagulant (heparine) at our disposal

The first thing we had to do was to construct a dialysator effective for clinical use A good dialysator must spread a small quantity of blood over a very large surface, the blood must circulate in a closed system and the blood as well as the washing liquid must be kept in continuous movement We must be able to clean and sterilise all those parts that come into contact with the blood so that they do not cause any pyrogenic reactions

After many earlier endeavours, briefly described elsewhere an artificial kidney was constructed in cooperation with Mr H TH J BERK, an artificial kidney which is suitable for clinical use

A detailed description of this artificial kidney is given, and a full set of drawings is given for its construction, so that any good instrument maker should be able to construct an artificial kidney Moreover instructions are given for its cleaning and sterilisi This is important in avoiding undesirable reactions of the patie such as rigors etc Detailed reports of the first 15 patients w were theated with the artificial kidney have been published the Dutch edition our experience with the artificial kidney h been analysed, the mistakes have been exposed in the hope making an uninterrupted vividialysis possible In this way lat treatments took place practically without technical interruptior

Through the dialysing membrane molecules go both in and ou therefore much attention has been paid to the composition of tl rinsing-liquid, as, in no circumstances may the patients be d

continue to give a chance to every severely uraemic patient who comes into our hands alive we shall never flatter our statistical results

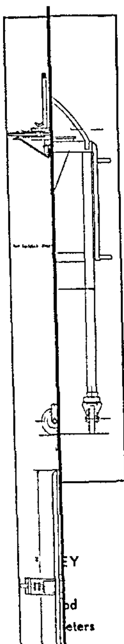
Some patients became uraemic owing to anuria or oliguria Others became uraemic though their diuresis was about 1 or 2 L. a day, but the concentration of the urine was poor This may be the case both in patients suffering from acute glomerulo-nephritis and in patients after operation

In cases of acute uraemia one should not postpone the treatment until the general condition of the patient suddenly declines We have come to the conclusion, that these patients nearly always die unexpectedly, whereas a short time before they still made clinically, a good impression

We propose to treat the patient with the artificial kidney as soon as the urea content of the blood rises over 350 mgr per 100 cc (3,5 grams per liter) and before that, if, moreover, the potassium content of the blood is higher than normal, or the alkali reserve is too low

If this is done, the urea-content can easily be brought under 100 mgr per 100 cc in one dialysis but this is usually not even necessary In the case of the 18th patient, the urea content was reduced to 46 mgr per 100 cc

It is now possible to deliver a seriously uraemic patient of his uraemia in one dialysis, which lasts from *5 to 14 hours*, so that, after the dialysis, he will have a several days' respite before the intoxication endangers his life again In the meantime there is a chance that the patient's own kidneys start excretion again


EY
od
eters

GROUNDPLATE FOR BLOODPUMP
Scale 1 30
Measurements in millimeters

RINSING BATH
Scale 1 3
tube hole
connected with $^3/_4$ '' tap
Measurements in millimeters (inside)

COUPLING
Scale 1 3
Chromed copper

PLAN II

HOLLOW AXLE, ETC
OF THE ARTIFICIAL KIDNEY

Scale 1 : 6

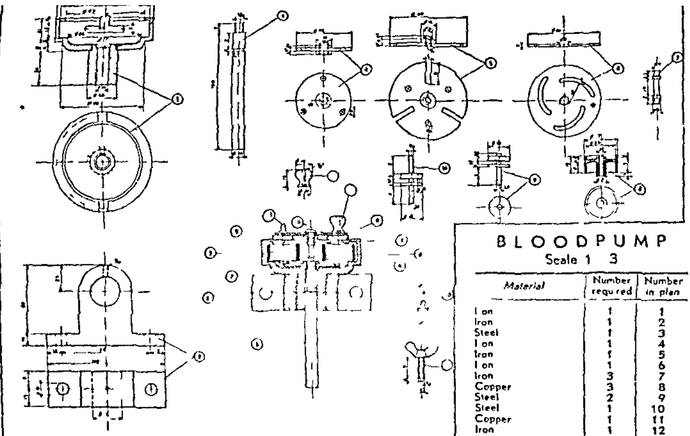
copper 1

All measurements in millimeters

FREEWHEELING AND
COUPLING OF BLOODPUMP

Scale 1 3

All measurements in millimeters



Material	Number requ red	Number in plan
I on	1	1
Iron	1	2
Steel	1	3
I on	1	4
Iron	1	5
I on	1	6
Iron	3	7
Copper	3	8
Steel	2	9
Steel	1	10
Copper	1	11
Iron	1	12
Iron	1	13

PLAN IV

KOLFF, W J *The artificial Kidney a dialyser with a great area* — Acta Medica Scandinavica Vol CXVII Fasc II Page 121 1944

— *Le rein artificiel un dialyseur à grande surface'* — La Presse Médicale No 7 Page 103 1944

11 KUHN, W, und K RYFFEL *Herstellung Konzentrierten Lösungen aus verdunten durch blosse Membranwirkung Ein Modell versuch zur Funktion der Niere* — Hoppe's Seyler's Zeitschrift fur Physiologische Chemie Band 276 Heft 4/6 Seite 145—178 1942

12 LIM and NECHELES, *Demonstration of a gastric secretory excitent in the circulating blood by vividialysis* — Proc Soc for exp biol and med Vol XXIV, page 197 1926—1927

13 NECHELES, H, *Ueber dialysieren des stromenden Blutes am Leben den* — Klin Wochenschr 2 II Seite 1257 und Seite 1888 1923

14 NYIRI W, *Experim Untersuchungen uber gekreuzte Bluttrans fusion bei Uramie* — Archiv fur Pathol und Pharmakologie 1926 Band 116 Seite 117

15 PAGE, J H, and O M HELMER *A crystalline pressor substance (angiotonine) resulting from the reaction between renin and reninactivator* — J of Exp Medicine 71, page 29 1940

16 PENDLETON A and WEST, Am Journ Physiol 101, 391 1932

17 POULSSON *Lehrbuch der Pharmakologie* 1919, blz 369

18 RHOADS J E, *Peritoneal lavage in the treatment of renal insufficiency* Am J of the Med Sciences Vol 196, 1938, page 642

19 STARKENSTEIN, *Lehrbuch der Pharmakologie, Toxikologie und Arzneiverordnung* 1938 blz 330

20 THALHIMER, W, *Experimental exchange transfusion for reducing azotemia* Use of artificial kidney for this purpose Proc. Soc for exper biol and med Vol XXXVII, page 641, 1938

21 THALHIMER, W, D L SOLANDT and C H BEST, *Experimental exchange transfusion using purified Heparin* Lancet 1938 II, page 554

PART II

PERITONEAL LAVAGE

This work has been performed with the assistance of P. S. M. Kop, M.D.

Principal

The principal of peritoneal lavage is very simple. A large quantity of rinsing fluid is allowed to run through the peritoneal cavity, the peritoneum serving as semi-permeable membrane. According to Wegner the surface area of the peritoneum is 17 000 squ. cm. If this figure is correct the area is almost equivalent to the estimated 20 000 squ. cm. for the total glomerular surface in the human kidneys. The peritoneal surface area, however, may not be the same as that of the underlying capillaries.

Development

The idea of peritoneal lavage is not new, although it has only recently been resuscitated. It is remarkable how widely spread in the medical literature of the world articles on the subject have appeared and equally remarkable how little the various authors have been aware of each other's work, with the result that they have repeated the same experiments and the same mistakes.

In 1923 GANTER published an article entitled "Removal of poisonous substances from the blood by dialysis". He injected a rinsing fluid into the abdominal cavity of guinea pigs after previously tying the ureters. On subsequent removal of the fluid it was found to contain the same concentration of urea as the blood. The same year TRACY PUTNAM investigated in detail the fate of various iso- and hypertonic solutions introduced into the peritoneal cavity. She was able to show that in certain circumstances the introduced fluid tends to become isotonic with the blood plasma; it appeared that some water was always absorbed from the peritoneal cavity [1])

---

1) Note at the correction. See also the work of LANSTEER ET AL and CROTSKI

In 1926 ROSENAK and SIWON used a continuous perfusion of the peritoneum in dogs They obtained the best results with 5 % glucose, although the removed mineral constituants had to be replaced by mouth HEUSSER and WERDER in 1927 did experiments on dogs VON JENY, and ROSENAK and BALASZ undertook some experiments ,about 1930, on peritoneal lavage in corrosive sublimate poisoning, the last mentioned authors treating two cases RHOADS published in 1938 two cases in which he had used peritoneal lavage, both patients subsequently died with chronic nephritis The rather poor removal rate of solids in these cases can be accounted for by the fact that fractionated lavage, i e a volume of fluid introduced, left in the abdomen, and then removed, was used, although on one occasion 20 g of urea was removed No effects were noticed on the pulse, temperature, respiration or blood pressure

In one of a series of cases published by WEAR, SISK and TRINKLE, the lavage brought about improvement in the patient's condition, a stone was subsquently removed from his bladder and he survived

ABBOTT and SHEA in 1946 published some careful work on the composition of the blood using a fluid very similar to our own Their conclusion that better removal of solids is obtained with an intermittent than with a continuous lavage does not seem likely to us FORMIJNE is, to our knowledge, the first to have used perfusion of the peritoneum in the Netherlands

FRANK, SELIGMAN and FINE (J A M A 19 March, 1946) published a successful case, in which anuria, following the use of sulphathiazole, was treated with lavage for five days, with only one period of intermission owing to some peritonitis That the authors should have had this therapeutic success was well deserved in view of their extensive work on dogs carried out beforehand

Technique.

A study of the literature has shown us no reason for changing the method we have developed, which, in principle, is no different from any other Up to the present we have performed 15 peritoneal lavages, and have so far no untoward experiences, except in the last case where a man with severe chronic uremia had a meteoristic abdomen A distended ileum-loop was perforated by the trochar, with the catheter in situ laparotomy was done, the hole was easily found and closed The patient died from uremia 3 days afterwards, at post mortem-examination no signs of peritonitis were found

Composition and preparation of the rinsing fluid

TABLE 21

Composition of rinsing fluids used by differen[illegible] aut[illegible]

grams per liter	RINGER tyrode	DARROW	RHOADS	HARTMANN	[illegible] ABLOTT & S [illegible]	art k[illegible]dne KOLFF	periton fl[illegible] KOLFF
NaCl	8.00	6.50	14.5	6.00	6.1	[illegible]	6.00
$NaHCO_3$	1.00	2,50			[illegible]	[illegible]	2.00
KCl	0.20	0.18	0.40	0.40	0.3	[illegible]	0.40
$CaCl_2$	0.20		0,20	0.20	0.[illegible]3		0.28
dextrose	1.00				1.1 [illegible]	10 30	10—30
lactic acid			2.40	2.4[illegible]			
NaH_2PO_4	0.05				0.07		
$MgCl_2$	0.10				0.05		

We should like to stress at this point that the electrolyte content of the rinsing fluid should be compared not with that of the plasma but of the plasma water (cf page 36)

We are not yet convinced that the addition o $MgCl$ and NaH_2PO_4 is necessary For the correction of the commonly present acidosis 200 mg % $NaHCO_3$ is added which is equivalent to a CO_2 content of 53 vols % To obtain a constant pH of 7.4 after sterilising 5 % CO may be bubbled through the fluid although we ourselves have no experience of this In some cases of oedema it was necessary to add up to 3 % glucose in one case we formed the impression that this caused abdominal pain during the lavage

To each litre of fluid 10 mg heparin is added in order to prevent clotting in the tubes of the protein containing fluid flowing out of the abdomen initially 40 mg of heparin is injected into the in flow tube at the beginning of the lavage Penicillin may be added to the rinsing fluid when cooled down after sterilising but it should also be given directly to the patient

In order to minimise the risk of infection we insist that the rinsing fluid is sterilised in a closed system which is not opened once sterile The reservoirs must be sufficiently large to avoid

frequent changes from one to another during lavage, again reducing the chance of infection

The enamel reservoirs were made for us to the pattern shown in fig 52 by the Berk enamel factory at Kampen. It would be simpler to use a single tank with a central partition but this is difficult to make in enamel

The inner tank is filled with 5 litres of fluid composed as follows 130 grams NaCl, 112 grams $NaHCO_3$, 11 grams KCl

The large outer tank is partially filled with 23 litres, as follows 280 grams dextrose, 8 grams $CaCl_2$ O aq, 192 cc HCl 10 %

The small tank is placed inside the large one, and the lid with a rubber washer, is screwed on The whole is sterilised by boiling for twenty minutes on a gasring Steam escapes through the small pipes covered with sterile gauze After boiling the reservoir is *cooled by placing in a bath of cold water Heparin is then added* and a sterile bung placed in the outlet tube The reservoir is now tilted 90°, the contents of the inner tank flow out into the outer and thourough mixture is ensured by shaking

Arrangement and sterilisation of the tubes

The arrangement of the tubes is obvious from fig 54 It is essential that the in-flow and out flow can be interchanged at a moment's notice At any time a loop of gut or a piece of omentum may block the out flow Not for nothing have several workers resected the omentum in their experimental animals before embarking on peritoneal lavage

The tubes should be cleaned as those in a transfusion set as is described on page 85

Rate of flow.

1 Liter per hour proved to be satisfactory

The introduction of the catheters into the abdomen

Several investigators have used glass or metal drains particularly for the out flow We have only had experience of thin catheters introduced through a trocar into the left side of the abdomen The catheters are pierced by a large number of small openings The lavage may flow uninterrupted for many hours or may require frequent reversal of direction

After carefully cleaning the skin and covering the surrounding area with sterile towels a small incision is made through the skin,

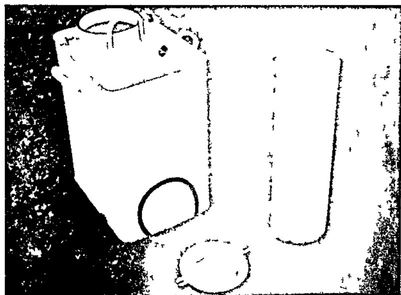


Fig 32
The small tank is placed inside the large one and the lid with a rubber washer, is screwed on The whole is sterilised by boiling for twenty minutes on a gasring

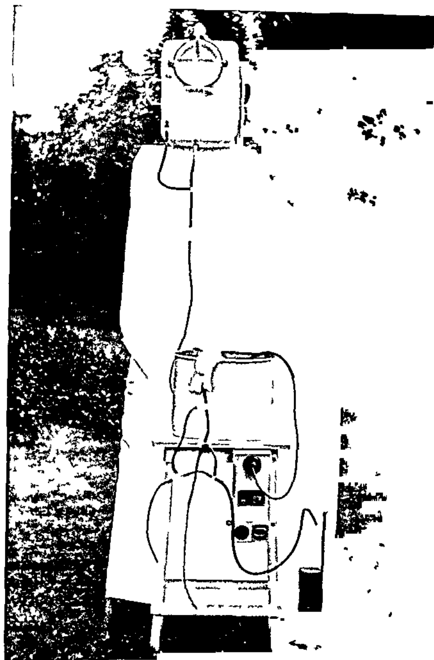


Fig 53
After cool ng the reservoir is tilted 90 the contents of the inner tank flow out into the outer and thorough mixture is ensured by shaking

DIAGRAM OF PERITONEAL LAVAGE

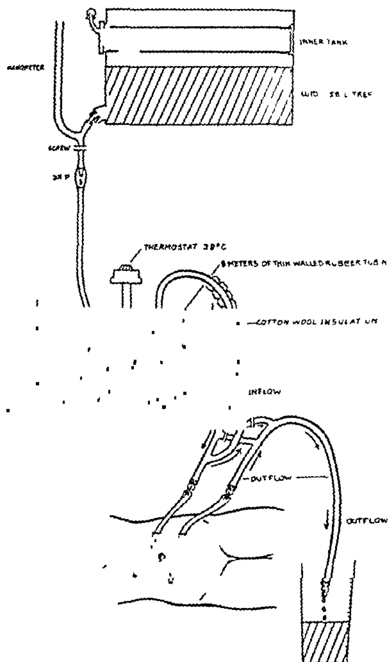


Fig 54
It is essential that the in-flow and out flow can be interchanged at a moment's notice At any time a loop of gut or a piece of omentum may block the out flow

and the trocar introduced with rotatory movements After inserting the catheter the cannula of the trocar is removed by slipping over it. The catheter is fixed to the abdominal wall by sticking plaster, and the wound powdered with sulphanilamide The chance of infection is considered very slight with the skin fitting tightly round the catheter, especially if the catheter is not left in longer than 36 hours Other workers introduce catheters or glass tubes by surgical means

The intestines appear to slip out of the way of the trochar In the case of marked abdominal retraction we have first injected 2 litres of rinsing fluid into the abdominal cavity by a needle in order to facilitate entry of the trochar by the artificial ascites *The puncture is made between the umbilicus and the anterior* superior iliac spine on the left side, the needle being directed obliquely downwards Care should be taken not to remain in the preperitoneal space, where the fluid will run in without any resistance, although(of course, the signs of ascites will not develop

Both stomach and bladder must be empty before starting

Trocars should not be used when the bowels are distended by meteorism

Patient A A man of 58 with a long history of bilateral renal and ureteric calculi The right pelvis became infected and this kidney ceased functioning An attempt to remove the stones from the right ureter 5 months previously failed owing to widespread Calcium deposits and scarring The left kidney continued to function well until the onset of renal colic on this side when complete anuria developed

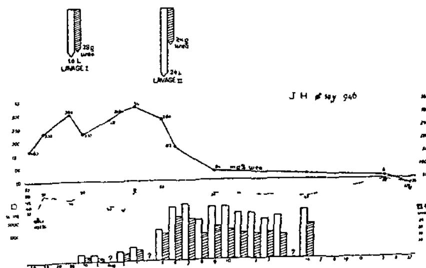


Fig 55

On cystoscopy a ureteric catheter could only be passed up to the stone on the left and diuresis did not start. When the blood urea had risen to more than 700 mg % peritoneal lavage was performed. The results may be seen in figure 55. The lavage lasted 16 hours and caused very little discomfort; an incipient rigor was aborted with dolantin and marked abdominal distension was reduced by temporarily stopping the in flow. Another lavage was performed later. Diuresis set in and the urine volume slowly increased. We believe that a more serious uraemia was prevented from developing in this man by peritoneal lavage.

Patient M. B. fig. 56. A tiny little girl of 9, said to have been ill for 3 weeks, was admitted with very pronounced uraemia. Blood urea 550 mg per 100 cc, alkali reserve 20¼ vols %, haemoglobin 3[illegible] %, blood pressure 105/70. She was dehydrated, irritable, psychotic, sleepy and very cyanosed.

lavages have been necessary and the question now arises how long it will be possible to continue with them [1])

Indications for peritoneal lavage

It is still very difficult to give the indications for treatment with peritoneal lavage. It should be considered in every case of acute uraemia that might otherwise end fatally. In chronic nephritis at most an extension of the patients life can be attained. The relative therapeutic values of peritoneal lavage and the artificial kidney cannot yet be assessed. FRANK, SELIGMAN and FINE state that the rate of urea clearance obtained with peritoneal lavage is in the region of 15 cc per minute; with the artificial kidney it is certainly more than 100 cc per minute. Peritoneal lavage is a more lengthy operation which in itself entails many disadvantages; on the other hand the artificial kidney requires a more complicated apparatus.

[1]) Note at the correction: She died after a convulsion; extremely contracted calcified kidneys were found at the post mortem. We have done 20 peritoneal lavages in 13 patients now, [illegible] of which recovered.

MB ♀ 9y, 1946

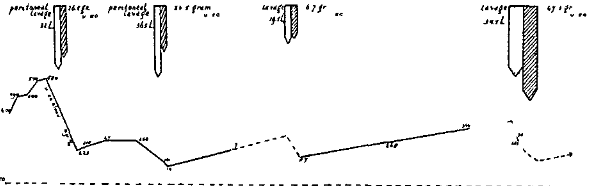
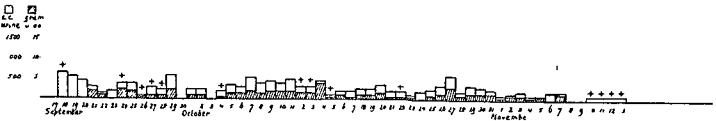



Fig 56

Pat B Girl of 9, presumably with chronic nephritis Temporarily kept alive by peritoneal lavage Maximum 24 hour urea excretion in the urine was 2 5 g It was not always possible to collect the blood specimens either immediately before, or immediately after lavage so that the values are not strictly comparable one to the other Moreover the girl's weight fluctuated considerably, first dehydration then oedema

	Peritoneal lavage	Artificial kidney
Contraindications		
Recent abdominal operations	+	—
Infection of abdominal wall or skin	+	—
Serious colitis	+	Danger of haemorrhages
Severe abdominal symptoms e g meteorism not uncommon in uraemia	+	—
Old adhesive peritonitis	+	—
Haemorrhages	—	+
Dangers.		
Infection	Peritonitis Dog and patient of Frank et al	Never seen
Gut perforation	Possible and observed, More likely with trochar than with surgical introduction of catheters	—
Gut invagination	Described in dogs	—
Haemorrhage	—	Possible due to heparin Blood transfusions effective
Shock	Possible and observed Can be treated	Likely Can be treated
Pulmonary oedema	Possible and observed Aggravated by raised diaphragm Sometimes due to absorption from peritoneum with reduced outflow difficult to combat, try increased glucose in rinsing fluid	Possible and observed *Treatment very effective* Indeed patients may have previously existing pulmonary oedema removed by treatment by artificial kidney
Rigors	Possible, not serious	May be very serious
Discomforts.	Occasionally severe abdominal pain with colic May feel very distended with vomiting Frequently no discomfort	Apart from possible rigors, none

*

LITERATURE PERITONEAL LAVAGE.

WEGNER, *Arch f klin Chir*, p 64, 1877
GANTER, *Munchen klin W'schr*, 70, II, p 1478 1923
PUTNAM, *Am J of Phys*, 63, p 548 1923
ROSENAK and SIWON, *Mitt a d Grenzgeb d Med u Chir*, 39, p 391, 1926
HEUSSER and WERDER *Beitr z klin Chir*, 141, p 38, 1927
VON JENEY, *Z schr f klin Med*, 122, p 294, 1932
ROSENAK and BALASZ, *Wien klin W schr*, 47 851, 1934
WEAR, SISK and TRINKLE *J of Urol*, 39, p 53, 1938
RHOADS, *Am J of the Med Sc*, 196, p 642, 1938
ABBOTT and SHEA, *Am J of the Med Sc*, —, p 312, 1946
FORMIJNE, *Ned Tydschr v Geneesk*, 90, p 1184, 1946
FRANK, SELIGMAN and FINE *J Am Med Ass*, 130, p 703, 1946
LANDSBERGER and GROINSKI, *Compt rend Soc de Biol* 93, p 787, 1925
SELIGMAN, A M, H A FRANK en J FINE, *Treatment of experimental uremia by means of peritoneal irrigation* J of Clin Invest, 25, p 211, 1946

PART III.

TREATMENT OF SERIOUS CHRONIC URAEMIA BY PERFUSION OF AN ISOLATED INTESTINAL LOOP

This work has been performed with the assistance of N K M de Leeuw

It has already been indicated in chapter I that the treatment of uraemia by induced diarrhoea has rightly or wrongly been generally abandoned In 1941 Dr GROEN reintroduced this therapy in Amsterdam PENDLETON has done experimental work with dogs he tied the gut at different levels forming pouches into which he injected various solutions Within a short time equilibrium was reached between the urea concentration of the blood and of the fluid in the gut loops Lit see p 90

During the war I heard of work in Poland using isolated intestinal loops in humans for dialysing I do not know the name of the responsible worker nor of any literature dealing with his attempts LANDSBERGER used the colon of animals making a appendicostomy Lit see p 100

SELIGMAN FRANK and FINE have compared the results of dialysing different sections of gut in dogs A constant length of 10 inches of jejunum and duodenum the ileum was slightly less and the colon much less satisfactory The clearance with a ten inch jejunal loop was about 10 % of the normal kidney function A single attempt in a human subject using the terminal part of the ileum gave unsatisfactory results Lit see p 100

If the figures obtained with dogs are correct it would seem that it must be possible by using a longer loop of gut, to maintain dogs in urea balance by dialysis alone although the body level of urea will be higher than normal The unfavourable results of HESSEL, PEKELIS and MELTZER should therefore not cause us to abandon the possibility of this form of therapy

Own Experiments.

I *Colon lavage through an appendix fistula*

In two patients with severe hypertension, contracted kidneys uraemia and persistent vomiting an appendix fistula was surgically induced Apart from the immediate object this allowed an easy

replacement of the water and electrolytes lost by the vomiting with a resultant improvement in the general condition In the first patient the thin faeces caused by the perfusion leaked through the anus and further lavage seemed inadvisable The urea concentration in the escaping perfusate was 38 mg per 100 cc as compared with a blood urea of 127 mg In the second patient the lavage was technically more satisfactory, as the sphincter ani had sufficient tone to close the thick rubber tube placed in the rectum so preventing the escape of the perfusate Although the blood urea was 300 mg per 100 cc the concentration in the perfusate was only 10 mg %

Colonic lavage seems of little practical importance as a method of dialysis

II *Lavage through an isolated loop of ileum*

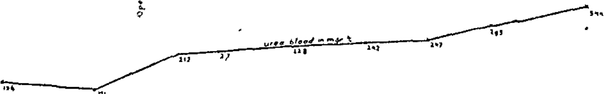
Technique A length of small intestine is cut transversely at both ends leaving the blood supply intact and the ends are sutured into the abdominal wall The continuity of the remaining intestine is restored by end to end anastomosis We used one meter of the terminal ileum for the isolated loop but we shall in future take a greater length

The rinsing fluid coming from the reservoir is led to the proximal end of the intestinal loop passing through a drip and a thermostatically controlled bath to bring it up to body temperature similar to the arrangement shown for peritoneal lavage The rubber tube between the warming bath and the gut opening must be insulated to prevent heat loss Regurgitation from the gut loop due to anti peristalsis may occur and therefore the inlet opening should also be included in the outflow cup

Case

H M 9831 (Fig 57) A man of 53 who had spent many years in the tropics had felt tired for two years six months before admission his symptoms became worse and albumen was found in his urine Despite a low protein and salt diet he steadily grew worse his vision became poor he suffered from insomnia and had vomited increasingly during the last four months Attacks of anginal pain sometimes very severe developed a few weeks before admission as well as nocturnal dyspnoea Muscular twitching and intense pruritus were also present [illegible] and marked [illegible] e liver was [illegible] own to the [illegible] hages were [illegible] occasional [illegible] cell the S G varied between 1005 and 1013

Exophthalmos and a basal metabolism of + 20 to 50 % suggested hyperthyroidism Thiouracil had no effect On x ray the heart was



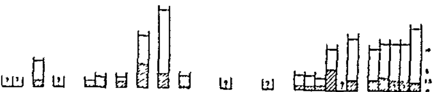
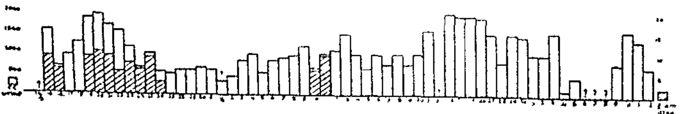



Fig. 57

A double-ended ileostomy with the isolated terminal meter of the ileum was performed. The largest quantity of fluid perfused at a single lavage through the ileal loop was 8 litres, and the best urea recovery was 5 g in 19 hours. It was not possible to prevent a gradual rise in the blood urea.

en to be enormously enlarged in both directions with bilateral pul onary congestion

The changes in the blood urea can be seen in the accompanying -aph Chlorides and alkalireserve were within normal limits Hb 53 % Diagnosis Malignant hypertension with contracted kidneys Uraemia d heart failure

The functional capacity of the kidneys under optimal conditions was timated The body could be kept in urea balance with a *daily urinary* itput of slightly less than 10 g of urea [1]) The increased fluid intake quired for this however led to a deterioration of his general con tion Apart from the difficulty of administering sufficient fluid to vomiting patient the sudden onset of an acute psychosis decided us to tervene

At our request an operation was performed on the patient by I ı KEHRER on 28/5/46 A double ended ileostomy with the isolated rminal meter of the ileum was performed the continuity of the rem ning gut being restored by end to end anastomosis Palpation of the dneys during the operation found them both very small and con acted Unfortunately a subcutaneous infection round the wound started st operatively and was only arrested by penicillin The concentric arring of the operation wound later resulted in contraction of the sto ata making perfusion of the loop exceedingly difficult This and some irther minor complications such as a boil over the sacrum prevented from doing lavage as regularly as we had hoped Frequently we had rest content with introducing 1 litre of fluid (with which it was ssible to replace the salt and water loss of the continuously vomiting itient)

The largest quantity of fluid perfused at a single lavage through the ı al loop was 8 litres and the best urea recovery was 5 g in 10 hours ıı was not possible to prevent a gradual rise in the blood urea

His cardiac condition

He was so eager to re

e necessary apparatus

ife who nursed him w

Commentary

1 In graph 2 (fig 58) it can be seen that the urea concentration in the perfusate varies inversely with the speed of flow In a very slow running lavage that is when the return flow is very small the perfusion fluid may contain more than 200 mg % urea

2 It will be seen from fig 59 that with a perfusion rate of 1 litre per hour the very good urea excretion rate of 0 48 g per hour is obtained. *It presumably does not offer any advantage to* perfuse faster The addition of $MgSO_4$ to the perfusate may account for the excellent results of the dialysis on this occasion

Had this patient been perfused during the whole twenty four hours he would have been maintained in urea balance The lavage

11 gram urea per diem Patients can remain

h a daily output of between 1 and 3 grams

ˑtion At present we would have tr ed to reduce th s on p 108

3 No diarrhoea or absorption abnormalities occurred that could be ascribed to the removal of a metre of ileum

4 Occasionally spasm and oedema of the stomata occurred, the outflow was checked, resulting in severe abdominal cramps It proved essential to start perfusion very slowly These cramps of the stoma could sometimes be relieved by inserting the little finger

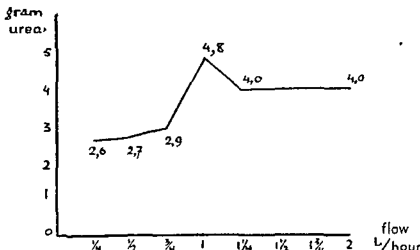


Fig 59
These figures are calculated for a dialysis of ten hours It was not always possible to carry out dialysis for the whole of this time

5 The perfusion fluid was the same as the bath-water in the artificial kidney, i e NaCl 0,6 g %, $NaHCO_3$ 0,2 g %, KCl 0,04 g %, glucose 1,5 g % This, however, resulted in a calcium deficiency

12-6-46 Perfusion fluid before dialysis { 1,3 / 1 1 } mg % Calcium

, ,, *after* ,, { 3,2 / 3,3 } *mg %* ,,

Later 28 mg % $CaCl_2$ was added to the perfusion fluid

-46 Perfusion fluid before dialysis { 8,3 / 8,2 } mg % Calcium

,, ,, after ,, { 8 / 8 8 } mg % ,,

The perfusate flowing out of the gut did not have any irritating effect on the surrounding skin

The isolated gut loop lavage is still in the earliest experimental stages It is far too soon to predict that those hopeless cases of chronic nephritis may perhaps be brought to lead useful lives In the daytime they would work, and at night they would keep their ileal lavage going

PART IV.

TREATMENT OF URAEMIA WITH HIGH CALORIC LOW PROTEIN DIETS

ı has been argued that at least 45 grams of protein is needed iaintain protein equilibrium in man This figure however has other basis than the 7 gr of nitrogen excreted per day, by ile who are fasting and represents only the bodies effort to t its caloric requirements by breaking down its own protein 'ı MPNER) J G G BORST in Amsterdam ı) and WALTER KEMP from Durham U S A) proved that if a patient is given high ric *low protein diet that then after some time the body spares* protein and the body protein consumption becomes so small t the urea excretion in the urine falls to 1—3 gr per day ' ıᴋEMPNER gave a ricediet to a large number of patients suffering ' ı hypertensive vascular disease and chronic nephritis He give tal of 2000 calories This gives about 5 gr of fat and 20 gr of ein not more than 0 2 gr of chloride and 0 15 gr of sodium ᴋ' 'IPNER is afraid of fat as he thinks that injured kidney cells ' the ability to oxydise keto acids KEMPNERS results are far ı er than would have been possible with any other form of treat ıt

› far our own experience although small seems to confirm this. BORST forces patients with severe uraemia to eat 200 gr of butter and 200 gr of sugar daily He is careful to see that if they vomit the lost quantity of butter and sugar is replaced The butter and sugar is served in the form of small balls from a refrigerator or is made into a kind of creamy soup by adding ± 12 gram of flour and coffee

Provided that the patients do not get diarrhoea and do not get too much meteorism the results are remarkable We have confirmed the fact that the urinary urea falls to 1 or 2 gr per day Thus it would be possible for a patient to have a complete anuria for 25 days or more, without contracting a serious uraemia '

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